THE EFFECT OF SECURITIZATION
ON THE CONVENTIONAL MORTGAGE YIELD SPREAD

By

IVY DENISE LOCKE

A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1993

Copyright 1993
by
Ivy Denise Locke

This would remain a distant dream if not for the inspiration, support, and encouragement I received from my family, friends, teachers, and colleagues. I express sincere appreciation to Mrs. Armentha Harvey Locke, Mr. Thomas Locke, Jr., Dr. Thomas Locke, III, Ms. Pat Harvey, Mrs. Geneva Harvey, Mrs. Iva Harvey Bynes, Mr. Solomon Bynes, Mr. Tommie Locke, Mrs. Catherine Locke, Mrs. Dawn Locke, Miss Tahira Locke, Miss Takeia Locke, Miss Tachena Locke, Dr. Leroy Gaskin, Mr. Paul Mikaya, Dr. Debbie Gunthorpe, Mr. Howard Rasheed, Mr. Anthony Graham, Mrs. Eloise Adams, Dr. Sharon Ames-Dennard, Ms. Gail Ayala, Mrs. Kristine Beck, Dr. Alan Bathke, Ms. Arlesia Brock, Dr. David Brown, Mr. Daryl Clare, Dr. Richard Corbett, Mr. Craig Collins, Mr. Ashley Cooper, Dr. Steve Cox, Ms. Jutta Court, Dr. Roy Crum, Ms. Carolyn Curry, Mr. Mark Dawkins, Dr. Micheile Dunlap-Martin, Dr. Sonya Ebron, Mr. Vasily Efimov, Mrs. Donna Eichhoefer, Mr. Charles Ford, Ms. Arglenda Friday-Dorsey, Mr. Audley Harris, Dr. Joel Houston, Dr. Lim Kok Chew, Dr. A. Khuri, Ms. Caroline Kreimer, Dr. Brenda Jarmon, Ms. Verdell Jefferson, Ms. Melody Johnson, Dr. Rod McDavis, Mr. John (Casey) Jones, Brother Ndugu Khan, Mr. Darius Lecoint, Ms. Wanda Lester, Dr. Andy McCollough, Dr. Gwendellyn Mingo, Dr. Smeul Nitzan, Mrs. Abeena Agyeiwa Owusu, Mr. Victor Powell, Dr. Hugh Pratt, Dr. Bob Radcliffe, Dr. Thomas Rees, Ms. Ena Ross-Green, Dr. Mike Ryngaert, Mrs. Connie Sadler-Lee, Dr. Kathy Stitts, Dr. Sloan Swindle, Dr. Vicmoia Sykes, Mr. Floyd Tyler, Ms. Sharon White, and Dr. Denise Woodbury. I thank God for each of you.

ACKNOWLEDGEMENTS

I give special thanks to the McKnight Foundation, the Florida Endowment Fund and its president Dr. Israel Tribble for financial and moral support throughout my doctoral studies.

I also express my sincere appreciation to The Florida State University Department of Finance, its chairman Dr. Don Nast and my mentor Dr. Steve Celec.

Additional gratitude is due to the Department of Finance, Insurance and Real Estate at the University of Florida. I am especially grateful to my dissertation chairman Dr. Miles Livingston and the members of my dissertation committee Dr. Wayne Archer, Dr. Hal Smith, and Dr. James Boyles for their patience and guidance.

TABLE OF CONTENTS

page

ACKNOWLEDGEMENTS iv

KEY TO SYMBOLS OR ABBREVIATIONS vii

ABSTRACT viii

CHAPTERS

1 INTRODUCTION 1

- Motivation 1
- Background 3
  - Historical Mortgage Market Practices 3
  - Innovations in the Mortgage Market 4
  - Implications of Mortgage Market Innovations 7
  - Historical Trends 9
- Contribution and General Hypotheses 11

2 LITERATURE REVIEW 16

- Pricing Models 16
  - The Valuation of Corporate Liabilities 17
  - The Difference Between Bonds and Mortgages 22
  - The Valuation of Mortgage Insurance 24
  - The Valuation of Mortgage Prepayment 29
  - The Valuation of the Entire Mortgage 42
  - Summary of Pricing Studies 61
- The Relationship Between Prices and Yield Spreads 63
- The Determinants of Interest Rates Spreads 67
  - The Determinants of Bond Yield Spreads 67
    - Summary of Bond Yield Spread Studies 74
  - The Determinants of Mortgage Yield Spreads 75
  - Alternative Analysis--Option Adjusted Spread 93
  - Summary of Yield Spread Studies 98

3 ANALYSIS OF THE CONVENTIONAL MORTGAGE YIELD SPREAD 100

- Contribution of Current Study 100
  - Alternative Methodologies 102
  - Studies Using Linear Regression 104

The Development of the Model....................105
    Dependent Variable..............................105
    Independent Variables...........................110
        Measures for Default Premium................111
        Measures for Prepayment Premium.............113
        Measures for Liquidity Premium..............114
        Measures for Other Yield Spread Determinants......116
    Statement of the Model..........................117
    Implied Assumptions of this Dissertation........123
    Specific Hypotheses.............................123
Data..125
Tests of the CONV-TREAS Absolute Mortgage Yield Spread......126
Tests of the CONV-TREAS Relative Mortgage Yield Spread......131
Summary and Discussion of Basis Point Effects.......136
Conclusion..142

4 CONCLUSIONS AND EXTENSIONS........................144

Description of Tests................................144
    Statement of the Absolute Equations.............144
    Statement of the Relative Equations.............145
    Statement of the Interactive Equations..........146
Discussion of Preferred Equations...................146
    Preferred Linear Equation for the Absolute Spread......147
    Preferred Interactive Equation for the Absolute Spread......148
    Preferred Linear Equation for the Relative Spread......149
    Preferred Interactive Equation for the Relative Spread......150
Extentions..152

APPENDICES

A THE REPLICATION OF RYDING (1990)..................154

B DATA SOURCES......................................159

BIBLIOGRAPHY..162
BIOGRAPHICAL SKETCH.................................167

KEY TO SYMBOLS OR ABBREVIATIONS

AAA-TREAS = spread between Moody's Corporate Bond Survey Aaa bond rate and the 10-year Treasury note rate

ABSCHG = absolute (positive) value of the prior month's Treasury rate minus the current month's Treasury rate

APTS = agency pass-through securities

β = a parameter in a regression equation

CMOs = collateralized mortgage obligations

CONV-TREAS = spread between conventional mortgage rate and 10-year U.S. Treasury note rate

DEREG = TREAS before usury ceiling removal and zero thereafter; Proxies for the operation of usury ceilings before 1983

FHA = Federal Housing Administration

FHLMC = Federal Home Loan Mortgage Corporation

FMHA = Farmers Home Administration

FNMA = Federal National Mortgage Association

FRM = Fixed-rate mortgages

GNMA = Government National Mortgage Association

MBSs = Mortgage-backed securities

OPMs = Option Pricing Models

%FHLMC = ratio of the FHLMC mortgage pool to the total mortgages pooled

%FMHA = ratio of the FMHA mortgage pool to the total mortgages pooled

%FNMA = ratio of the FNMA mortgage pool to the total mortgages pooled

%GNMA = ratio of the GNMA mortgage pool to the total mortgages pooled

%POOL = ratio of total mortgages pooled to total mortgages outstanding

%PRIV = ratio of the Private mortgage pool to the total mortgages pooled

S&Ls = Savings and Loan Institutions

STRIPS = mortgage strips, which convey some fraction of the interest and principal payments from underlying mortgages

TREAS = 10-year U.S. Government Treasury note rate

Note: When these variables are preceded by "R", they are calculated as indicated above and divided by the Treasury rate to create a relative variable.

Abstract of Dissertation Presented to the Graduate School of
the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Doctor of Philosophy

THE EFFECT OF SECURITIZATION ON THE CONVENTIONAL MORTGAGE YIELD SPREAD

By

Ivy Denise Locke

May 1993

Chairman: Miles B. Livingston
Major Department: Finance

This dissertation develops a model that captures the effects of securitization on the conventional mortgage yield spread. Using quarterly data for the United States from 1974 to 1990, the study considers evidence of how security innovation affects the yield spread between conventional mortgage rate and the 10-year U. S. Treasury note rate.

Statistical tests find significant relationships between the mortgage yield spread and certain measures of mortgages pooled and traded in the secondary mortgage market. The liquidity effect of securitization is found to be significant when default risk and prepayment risk are controlled for. With interactive models, additional significant liquidity effects are noted. Lastly, the economic impact of the liquidity premium is measured by converting the interactive liquidity effects into basis points and dollar values.

CHAPTER 1
INTRODUCTION

This study considers the relationship between the securitization[1] of mortgages and the conventional mortgage yield spread.[2] By providing an active secondary market in which mortgage cash flows can be resold, securitization has increased liquidity for mortgage investors and makes the mortgage contract a competitive investment alternative. The analysis considers the impact of the integration of real estate capital markets with the general capital markets.

Motivation

Over the observation period, real estate investments partially lost their formerly protected position in the credit markets. Deregulation of financial institutions made mortgage lending more competitive by loosening the constraints on the portfolios of the savings and loan institutions (S&Ls). In 1980, the Depository Institutions Deregulation and Monetary

---

[1] Maisel (1987) defines securitization as the process of converting mortgage loans into securities with a wider market acceptance by using them as collateral behind these securities.

[2] The mortgage yield spread refers to the difference between the conventional mortgage contract rate and the 10-year U.S. Treasury note rate.

Control Act authorized nationwide NOW accounts and authorized the investment of up to 20 percent of the assets of federal associations in consumer loans, corporate debt securities, and commercial paper.[3] Before that time, mortgage lenders were subject to the usury ceilings that limited the interest that could be paid on deposits in financial institutions. After substantial disintermediation in the early 1980s, the usury ceilings were removed to allow these institutions to pay competitive rates on deposits. The Tax Reform Act of 1986 reduced the portion of qualifying S&L assets of bad debt reserve from 40% to 8% of taxable income. Before these changes, S&Ls enjoyed protection from competitive forces.

During the same period, the expansion of securitization in the secondary mortgage markets provided new investments to narrow the gap between the investor needs satisfied in the mortgage market and other debt markets. This study focuses on events considered major changes in the way mortgage markets operate. In the primary market, the introduction of adjustable mortgages has allowed lenders and borrowers to negotiate risk bearing for various features of the mortgage contract. In the secondary market, many new procedures and securitization practices were initiated by both the government and private sectors.

---

[3] Congressional Budget Office (1983).

Background

This section discusses the history of the mortgage markets and the implications of the security innovations of the last two decades. Next, historical trends in the levels of interest rates, the mortgage yield spread, and volume of mortgages outstanding and securitized are disclosed.

Historical Mortgage Market Practices

Before the deregulation of financial institutions and the securitization of mortgages, the real estate capital markets were less integrated with the general capital markets. Historically, the U.S. government provided favorable tax treatments to encourage real estate investment, home ownership, and certain types of property development. Real estate financing tended to be long-term fixed-rate mortgages secured by specific property. Due to the geographic specificity of the property, information regarding properties was more easily obtained by regional lenders. The secondary mortgage market principally involved the resale of the cash flows of an entire mortgage contract as a single security. A mortgage investor needed substantial financial capacity to buy and hold these securities that could not be readily resold. Such limited marketability instruments suited the needs of the clientele of some large investors with low liquidity needs and a long investment horizon. Thus, the traditional secondary market was restricted to large investors like insurance companies and pension funds.

Currently, mortgages are not only collateralized by property, they are also insured and/or guaranteed. These risk-shifting arrangements include private or government insurance and/or government guarantees. In fully private insurance arrangements, the insured party pays the full expected costs that the insurer incurs in providing the insurance. To make the insurance worthwhile, premiums are lower than the expected losses to the insured party. The private insurance company does not expose itself to expected losses any larger than the revenues it collects from those it insures, less an allowance for return on capital. Hence, no one is exposed to more risk than is prudent, so no incentives for risk taking can be said to be distorted by this arrangement.[4] With government insurance or guarantees, the government may subsidize insurance costs by bearing more risks than justified by the fee or premium.

Innovations in the Mortgage Market

Since 1970, the secondary mortgage market has expanded due to securitization. The government and quasi-governmental agencies offer securitized mortgages in the form of agency pass-through securities (APTS), collateralized mortgage obligations (CMOs), and mortgage strips (STRIPS). The private sector mortgage securities include mortgage-backed commercial paper, mortgage-backed bonds, private pass-through certificates, mortgage pay-through bonds, private collateralized mortgage obligations, and subsidiary preferred stock.

---

[4] Downs (1985).

The securitization process began with the 1970 Government National Mortgage Association (GNMA) offering of agency pass-through securities collateralized by pools of Federal Housing Administration (FHA-insured) and Veteran Administration (VA-guaranteed) seasoned mortgages. Although a secondary market already existed to trade whole mortgage instruments, the GNMA APTS represented the first securities that pooled mortgage loans into highly marketable securities. By 1971, the Federal Home Loan Mortgage Corporation (FHLMC) offered interests in pools of conventional mortgages.

In 1979, a new primary mortgage instrument was introduced when federally chartered S&Ls were authorized to issue adjustable mortgages. Not until 1981 did the FHLBB permit national banks to offer adjustable-rate mortgages (ARMs). These mortgages met the needs of investors who sought fluctuating returns. Among the adjustable features of the nouveau mortgages of the late seventies were the interest rate, the payment structure, and the term. The most common feature was the adjustable rate that varied according to an index specified at the loan origination date. Adjustments were typically subject to caps as specified in the loan document. Although a primary mortgage that was not frequently securitized, ARMs were considered in many analyses of structural changes in the mortgage market because of their popularity during the securitization boom.

The June 1983 introduction of Federal Home Loan Mortgage Corporation (FHLMC) CMOs allowed cash flow segmentation by the timing of the cash flow. With CMOs, investor liquidity needs could be matched with the characteristics of the cash flows. CMOs allowed traders to sell the pieces for aggregate values greater than the value of the whole mortgage. Also by 1983, the usury ceilings on interest paid on deposits in financial institutions had been phased out.

In July 1986, lenders were allowed to rebundle mortgage cash flows into mortgage strips. These unique securities were offered by FNMA and private issuers. A strip passed through to its investors some fraction of the interest and principal payments from underlying mortgages or mortgage-backed securities. For a premium security or interest only (I/O) security, the holder received larger fractions of the interest payments than of the principal payments. Investors in discount or principal only (P/O) securities received smaller fractions of the interest payments than of the principal payments. The I/O strips were popular for hedging prepayment uncertainty because their duration is actually negative.[5] When interest rates rise, I/O prices also rise, in contrast with most fixed-income securities. When interest rate levels are volatile, portfolios that hedge with I/Os must be constantly monitored and balanced to stabilize portfolio value.

---

[5] Lloyd-Davies (1987).

Implications of Mortgage Market Innovations

Like other investments, mortgages are subject to default risk, reinvestment risk,[6] price risk, and prepayment risk. To diversify regional default risk and reduce secondary market investor exposure to default risk, lenders re-package seasoned mortgages as mortgage-backed securities and quasi-governmental agencies guarantee timely payment of the cash flows of the securitized contract. Further, APTS, CMOs and STRIPS are collateralized by the underlying mortgage instrument. However, securitization does not remove all risk. Uncertainty remains regarding default, interest rates, price changes, and prepayment trends. Though the derivative securities do not represent new issues, the additional options and liquidity available to the mortgage investor make mortgage investments more attractive and therefore provide incentives for the expansion of mortgage originations.

The market segmentation theory states that investors have strong preferences about the maturity structure of their financial borrowing and lending. These preferences tend to create financial asset demand and supply conditions that are unique to each maturity segment of the yield curve. Interest

---

[6] Reinvestment risk is a form of interest rate risk where an investor must consider the timing of cash flows and projections of interest rate levels to estimate anticipated returns.

rates within each segment are determined largely by current demand and supply within that segment.[7] If the market segmentation theory is true, securitization will enable the mortgage market to satisfy additional investor needs.

With an active secondary market, mortgages can compete for funds in integrated capital markets. Cash flows can be partitioned outside the original loan documents to meet the individual investor liquidity needs, reinvestment risk preferences, and maturity risk preferences. Unlike the primary market, the secondary market with truncated securities allows a diverse group of investors to fund portions of a mortgage. Investors with shorter horizons can fund earlier cash flows. Because mortgage-backed securities can satisfy investment needs for interim and shorter investment horizons, the mortgage market can now have maturity market segments within the market instead of catering solely to the long-term investor.

Securitization should decrease the conventional mortgage yield spread over Treasury rates because of the reduction in default risk exposure and the increased liquidity of mortgages. Less profit (in the narrower spread) should eliminate inefficient mortgage originators who do not have cost effective means to screen borrowers and service mortgages. Larger differences between mortgage yields and U.S. Treasury yields before the securitization of mortgage instruments and smaller spreads after each securitization event are expected.

---

[7] Radcliffe (1987).

Since securitization involves the repackaging and resale of the cash flows in a mortgage contract, mortgages held by financial institutions should decrease, but total mortgages outstanding should increase as more holdings flow through to the secondary markets. An implication of this result is that securitization provides an additional funding source that is expected to increase the volume of mortgage originations despite the anticipated lower marginal profitability.

Historical Trends

Since this paper focuses on how securitization affects the mortgage yield spread, the data presented in this section offer the available measures for the variables of interest. The proposed tests of theories to explain variable behavior will be detailed in Chapter 3.

Figure 1-1 shows a time series of conventional mortgage rates and of 10-year U.S. Treasury rates from 1974 to 1990. The correlation of these two rates is a positive 96.3%. The standard deviations from the mean of 11.5% for conventional rates is 2.5% and from the mean of 9.4% for the 10-year Treasury rate is 2.3%. Although the direction of the movements occurs simultaneously, the spread between the rates varies. As shown in Figure 1-2, the difference between the conventional and 10-year Treasury rates (CONV-TREAS) is

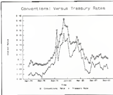

Figure 1-1 A comparison of the conventional mortgage rate and the 10-year U.S. Treasury rate.

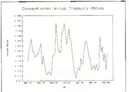

Figure 1-2 The net of the conventional mortgage rate minus the 10-year U.S. Treasury rate.

volatile. This spread compensates investors for the changing differences in default, prepayment, and liquidity risks in the two securities.

Contribution and General Hypothesis

Prior studies provide limited, if any, treatment of the effects of securitization on the mortgage yield spread. The current analysis introduces tests for structural change to capture the effects of the introduction of new mortgage securities.[8] The general hypothesis of this study suggests that securitization should have an impact upon the mortgage yield spread. The securitization of primary mortgages is expected to make mortgages more liquid and therefore a more actively traded investment vehicle. The mortgage yield spread (CONV-TREAS) should be smaller, and total mortgage supply should rise and become a less binding constraint on housing starts. This has important implications for public policy and the continuing federal role in the housing credit system. In the presence of more competitive securities, housing finance may reap minimal benefits from continuing protectionist regulations for major housing lenders. Housing would compete for funds on a more even footing with other types of investments. Mortgage markets would behave more like other debt markets.

---

[8] Structural change tests incorporate interactive quantitative and dummy variables to capture shifts in the parameters generating the data. We measure changes in the linear estimates of the dependent variables at the securitization dates in question.

Mortgage debt is one of the largest sources of private debt. Figure 1-3 pictures the total mortgages outstanding and the total mortgages pooled. Over the observation period, the volume of mortgages outstanding averaged $1,868 billion. The volume of mortgages pooled averaged $331 billion. By the end of the observation period, the volume of mortgages pooled had grown to $1,103 billion.

Prior studies have considered the percentage of mortgages pooled as a measure of liquidity. It is interesting to observe the growth in the percentage of mortgages pooled. From 1970 to 1990, the percentage of mortgages pooled grew from 0% to 28.63%. The climbing trend in the percentage of mortgages pooled is depicted in Figure 1-4.

A unique contribution of this study is the employment of agency market share measures as proxies for the liquidity premium in the mortgage yield spread. Figure 1-5 Panels A, B, and C show pie charts that reveal how the market was split between GNMA, FNMA, FHLMC, FNMA and private issuers of mortgage-backed securities in 1974, 1984, and 1990. Although GNMA pass-through securities dominated for the entire horizon, competition from the other agencies fluctuated when new types of securities were introduced. By studying the agency market shares, the effect that each agency has on the conventional mortgage yield spread can be unveiled.

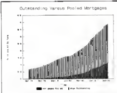

Figure 1-3 Comparison of mortgages outstanding and mortgages pooled.

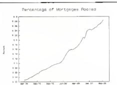

Figure 1-4 The ratio of volume of mortgages pooled to volume of mortgages outstanding

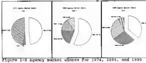

Figure 1-5 Agency market shares for 1974, 1984, and 1990

During the observation period, there were numerous structural changes in the mortgage market. Figure 1-6 depicts a time line highlighting major changes in how the primary and secondary mortgage markets operated for the past two decades. Mortgage securitization, the removal of usury ceilings and the creation of new mortgage securities transformed mortgage lending. This study measures the impact of these changes on the mortgage yield spread.

In the chapters that follow, related literature is reviewed, tests of the mortgage yield spread are discussed, the statistical results are analyzed, and conclusions and extensions for future research are suggested.

The next chapter surveys the literature for pricing models and yield spread studies.

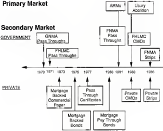

Figure 1-6 Structural Changes in the Mortgage Market

CHAPTER 2
LITERATURE REVIEW

The literature review chapter of this dissertation describes previous studies that considered topics or methodologies that are related to the effect of securitization on the conventional mortgage yield spread. Although this dissertation studies the determinants of the conventional mortgage yield spread, the dominant topic in the real estate finance literature is valuation. To report what scholars have learned about mortgages, this chapter is divided into three sections. The first section discusses studies that analyze the valuation of corporate liabilities and mortgage related securities. The second section identifies the relationship between yield spreads and the prices tested by the pricing models. The third section reviews studies that investigate the determinants of interest rate spreads involving corporate bonds, U.S. Treasury securities and mortgage contracts.

Pricing Models

Most popular mortgage valuation models build on relationships established in the analysis of other financial securities.[1] Debt and option values are important to this dissertation because mortgages are debt instruments that include options that could lead to termination before the maturity date. Therefore, this literature review begins with a discussion of fundamental research on corporate instruments. Following the discussion of bond valuation models, a section discusses differences between bonds and mortgages.

---

[1] See Black and Scholes (1972, 1973), Merton (1973, 1974), and Brennan and Schwartz (1977, 1979)

Next, valuation models for mortgage default and prepayment are discussed. The pricing model discussion ends by reviewing studies that value the entire mortgage contract.

The Valuation of Corporate Liabilities

Black and Scholes (1973) assumed continuous perfect markets,[2] constant interest rates, and constant variance of returns with a lognormal continuous stock price distribution to derive a general equilibrium option pricing model (OPM) for European[3] options on a no-dividend stock.

Black and Scholes (1973) modeled the call[4] option value as a function of the price of the underlying stock, the exercise price, the short-term risk-free interest rate, the time to expiration, and the variance of the stock returns. To justify use of the risk-free rate, they approximated a riskless hedge that identified the number of shares that an investor should hold to balance a short call option. Merton (1973) noted that the Black-Scholes model produced an option price that was independent of the expected return on the underlying security, risk preferences of investors or the aggregate supplies of assets. An additional attraction was that the Black-Scholes variables could be observed directly except the variance parameter, which could be estimated.

---

[2] The term "perfect markets" refers to capital markets that are characterized by trading with no transactions costs, information costs, taxes, institutional constraints or regulations that affect investor returns, market access and asset divisibility or marketability.

[3] A European option can only be exercised at maturity unlike the American option that can be exercised at any time between issuance and maturity.

[4] A call option was the right to buy a given number of shares at a stated price from issuance to a specified expiration date.

Black and Scholes (1972) tested the sensitivity of the OPMs to the variance estimation method. When estimating the variance from actual prices over the life of the options, the model performed very well. When the historical price variance was used, the model overestimated option value on high variance securities and underestimated option value for low variance securities. When transactions costs were added, Black and Scholes (1972) found no profit opportunities.

Besides the likely heteroscedasticity in the variance of stock returns over time, other empirical limitations of the Black and Scholes OPM included lack of continuity in stock prices and in option market trading. Additionally, the presence of transactions costs made continuous rebalancing of a hedged portfolio impractical. Black and Scholes (1973) acknowledged that the option holder must protect against distributions affecting price. This idea was considered further by Merton (1973, 1974).

Merton (1973) assumed investors preferred more to less to derive the Black-Scholes OPM without general equilibrium or distributional constraints on stock prices. To avoid maturity risk differences, Merton suggested using a risk-free rate with the same term as the option valued. Allowing for changes in risk-free rates, exercise prices and term, Merton (1973) used the Black-Scholes model to value options, bonds, and stocks with constantly proportional dividends. Merton (1973) showed that protection against dividends or large unfavorable exercise price changes prevented premature exercise of an American call.

Merton (1974) showed that the value of a bond depended upon the term structure of risk-free interest rates, debt class liquidation restrictions in bond covenants, and unanticipated changes in the probability of default. The risky bond was equivalent to holding risk-free debt and a short put[5] to the stockholders. The default risk premium on risky corporate debt was the yield-to-maturity on the bond as priced in the OPM minus the risk-free rate.

Merton (1974) modelled the default risk premium as a function of the variance of the firm's operations, debt maturity, and the debt payment to firm value ratio. By capturing the corporate default risk, Merton (1974) provided a more realistic tool to value corporate bonds with call options and uniform or continuous coupons.

---

[5] A put option was the right to sell a given number of shares at a stated price from issuance to a specified expiration date.

Brennan and Schwartz (1977) applied Black and Scholes (1973, 1974) and Merton (1973, 1974) to compare the value of a straight bond to bonds with contingent claims--savings bonds,[6] retractable bonds,[7] and callable bonds.[8] If interest rates followed a Gauss-Wiener process[9] and the pure expectations hypothesis[10] held, they described bond valuation as a function of interest rates, the coupon rate, time, and boundary conditions that reflected how the contingent claim reacted to interest rates. They also assumed no default risk, a single coupon rate, an immediate effect for elected options, and negligible differences in the liquidity of the bonds. With these simplifying assumptions, they identified the relative values of the contingent claim bonds and a time series of critical rates at which bonds should be redeemed

---

[6] The savings bond coupon rate increased over time. Like an American put option holder, the investor in a savings bond could redeem at par at anytime before maturity.

[7] Like European options, retractable bonds could be redeemed on a specified date.

[8] Callable bonds were equal to straight bonds minus the value of an American call option to purchase the bond at par

[9] The Gauss-Wiener process was a stochastic process where the expected rate is constant with a constant standard deviation.

[10] Under the pure expectations hypothesis, the instantaneous expected return on risk-free securities of all maturities equal

Brennan and Schwartz (1977) showed that valuation procedures determined the optimal strategy for exercising the option.

Brennan and Schwartz (1979) empirically tested the continuous time approach to price default-free bonds without call or retraction options. They assumed that instantaneous interest rates followed a Markov process, utility dependent functions were constant, the term structure of interest rates could be estimated by the current yields on default-free bonds with the longest and shortest terms in a Gauss-Wiener Process, and the standard deviation of unanticipated instantaneous changes in each interest rate was proportional to the current level of that rate. Contrary to prior models,[11] Brennan and Schwartz (1979) attempted to explain the intermediate yield curve in terms of the extremities.

In the theoretical model, the short-term rate was an instantaneous rate of interest and the long-term rate was the yield on a consul bond with continuous coupons But, the rates used in the model were from 30-day Canadian Bankers' Acceptances and Government of Canada bonds with a finite term over 10 years. Brennan and Schwartz (1979) asserted that the model was appropriate for all interest dependent contingent claims; yet, they tested it by pricing 101 optionless Government of Canada bonds with maturities less than 10 years. For alternative values of the instantaneous interest rate, the model explained approximately 93% of the volatility in the prices estimated.

---

[11] See Merton (1973) and Brennan and Schwartz (1977).

The seminal bond studies discussed in this section established a foundation upon which mortgage researchers built elaborate models to value complicated mortgage agreements. The consensus was that corporate liabilities with contingent claims were reasonably priced using OPMs. This implied that the options on real estate loans made mortgages behave like straight bonds plus a set of options.

The next section describes complexities of mortgage agreements that distinguish them from corporate bonds.

The Difference Between Bonds and Mortgages

This section covers additional features that must be considered by mortgage analysts. Mortgage borrowers have the option to default, prepay, or pay late. Lenders choose the set of covenants in the contract and the type of insurance required, if any. If the agreement is violated, the lender has the option to foreclose. The foreclosure laws differ by region and are beyond the scope of this dissertation.[12] This dissertation is concerned with other differences between bonds and mortgages that are discussed broadly in this section and in more specific applications reported in the subsequent sections on mortgage pricing and mortgage yield spreads.

---

[12] For more information about the impact of foreclosure laws on the mortgage market, see Clauretie (1987), Longbrake and Peterson (1979), and Meador (1982)

Other differences between bonds and mortgages lie in the efficacy of the contract. An effective contract reduces a borrower's incentive to assume additional risk when using the lender's money.

Smith (1982) asserted that unlike bond indentures, the contractual provisions of mortgages were efficient solutions to the conflict between lenders and borrowers. By requiring a down payment, limiting the rental of property and requiring the borrower's homestead as collateral, the lender encouraged the borrower to protect the property. The use of escrow accounts forced the borrower to maintain hazard insurance and pay property taxes. Borrower payments of application fees, appraisal fees, and closing costs also decreased the probability of default. Smith (1982) suggested that mortgage terms decreased foreclosure expenses, as well as processing, monitoring and administration costs.

The differences between bonds and mortgages also included frequency of payments[13] and other factors that would affect the lender's return. Mortgage yields depended on the location of the collateral, the usury and foreclosure laws of the region, the types and concentration of lenders, the operating costs of the lenders, the product mix offered by lenders, and the risks of default, prepayment and marketability.[14] This dissertation is primarily concerned with the marketability effects. Liquidity has been available in the mortgage market for just over two decades, but the default and prepayment issues dominate the literature. Because the latter factors are also priced, this review devotes the following sections to a study of insurable default and the most frequently cited prepayment studies.

---

[13] Most bonds paid interest semi-annually and principal at termination compared to mortgages that had monthly amortizing payments of principal and interest.

The Valuation of Mortgage Insurance

Swan (1982) described the difficulties in pricing private mortgage insurance. The factors affecting mortgage insurability changed frequently and the borrower's incentive to default grew as the value of the property dropped. Though the borrower could not influence extra-home value, he affected the value of the property as the caretaker of the owner-occupied collateral. The borrower also could cause a negative equity position by missing payments, allowing interest to capitalize, and the loan balance to increase. Despite the incentives to default, borrowers had an interest in protecting their home, equity investment, and long run credit capacity.

Swan stated that mortgage insurance reduced risk for mortgage originators, secondary market investors, and federally sponsored credit agencies. In an option pricing framework, Swan described the position of the uninsured lender: the lender made a risk-free loan and sold a put option to the borrower. The borrower would exercise the option and exchange the house for the mortgage if the house value fell below the loan balance. Justifiably, most lenders required the borrower to get some type of mortgage insurance.

---

[14] These factors were examined by Longbrake and Peterson (1979) and Sandor and Sosin (1975).

Swan discussed the practices of independent and self-insurance. The mortgage originators had a comparative advantage at protecting themselves from "micro-risk" factors through strict underwriting terms. Private secondary market investors more readily obtained geographical diversification in their loan portfolio. Federally sponsored credit agencies enjoyed similar diversification opportunities, still they required mortgage insurance on low down payment conventional loans and more recently additional insurance on an entire pool of mortgages. For private insurance, Swan acknowledged that scholars believed the private mortgage insurers enjoyed monopoly rents due to the small number of providers for many lenders. With significant growth in both the federally sponsored credit agencies and the private mortgage insurance industry, the mortgage default risk shifted. These factors worked in concert with the deregulation of mortgage issuers to force competitive pricing of mortgage contracts.

In an untested model, Swan defined the value of private mortgage insurance policies as the net present value of the premium income, the cost of issuance and the funds available after the reserve period (net of losses on claims). Because many mortgage insurance premiums were constant for long periods, it was difficult to assume that premia were optimally set using time value of money calculations. Some of Swan's ideas were empirically tested in Campbell and Dietrich (1983) and Cunningham and Hendershott (1984).

Cunningham and Hendershott (1984) developed and tested a model to identify fair premia on mortgage default insurance for the Federal Housing Administration (FHA). The authors used alternative assumptions regarding taxation,[15] house-price inflation rate, the variance of house-price inflation rates, and homeowner default costs. The model was tested using mortgage contracts that varied by amortization schedule, nature of payment, and initial loan-to-value ratios.

Cunningham and Hendershott recognized that the gain from defaulting included the net of mortgage value less house value and the free rent earned between default and foreclosure. The costs of default varied depending on housing alternatives, legal constraints, the existence of attachable assets and what Cunningham and Hendershott called "psychological aversion" to default.

---

[15] In an appendix, Cunningham and Hendershott (1984) decomposed the insurance premium into components that were taxed at appropriate rates depending on the tax bracket of the home buyer and the purchaser of the insurance policy. They found that the model did not change for the no-tax model. Therefore, there will be no discussion of tax effects in this review of their study.

By making rather arbitrary assumptions, Cunningham and Hendershott incorporated the default option trade-offs into the Black and Scholes (1973) framework. In this framework, the household formed "a riskless hedge including the purchase of a partially debt-financed house and the appropriate number of insurance contracts on the mortgage."[16] They developed a model of the value of the insurance upon the default as a function of the mortgage rate, the mortgage balance, and the critical house price. Cunningham and Hendershott assigned a mortgage rate of 13% and a risk-free rate of 11.5%. The difference of 1.5% was an estimate of the prepayment risk premium.[17] They used this admittedly high estimate for simplicity and conservatism.

Cunningham and Hendershott reported price estimates for three values of the default cost parameter, four types of mortgages, and four loan-to-value ratios. Their estimates of insurance fees were reported as an up-front price as a percentage of initial mortgage balance, and an annual equivalent fee as a percentage of the outstanding mortgage balance. The fees were higher for higher loan-to-value ratios, longer terms, and lower default costs. The variation in the fair insurance premiums was large and independent of the costs of default, or to the level of inflation across loan-to-value ratios. With changes in the mortgage amortization period, higher inflation prompted increases in the default premia. With lower interest rates, the fair premia dropped reflecting the reduction in the expected loss from default.

---

[16] Cunningham and Hendershott (1984), 379. The authors noted that the number of contracts purchased would be lower for a lower down payment. However, the premium paid to the insurer would be higher.

[17] The expectation that the price of this risk was identical for different instruments was based on Buser and Hendershott (1984), which is discussed in detail in the section on the Valuation of Mortgage Prepayment.

In an extension, Cunningham and Hendershott found that the cost of default risk on 80% conventional loans was identical with the fee that FHA should have charged for an 80% loan-to-value ratio mortgage. This implied that with the same real risk-free rate, the same liquidity, and the same prepayment risk, the CONV-FHA spread would have a value not significantly different from zero.

Cunningham and Hendershott concluded that the borrower's default decision was driven by his moving costs. They showed that in an inflationary environment, there was a critical house price at which the borrower had the economic incentive to default, but other nonfinancial considerations increased the opportunity cost of defaulting. This suggested that significant negative equity must occur before default was economically justified.

Smith (1982) implied that mortgage insurance helped to resolve conflicts between borrower and lender. Factors affecting insurance value are dynamic and therefore were accompanied by self-insurance practices.[18] Cunningham and Hendershott noted that mortgage insurance premia valued with GPMs did not approximate the costs of default.

The next section discusses another option that accompanies the default option in a mortgage--the prepayment option.

The Valuation of Mortgage Prepayment

Curley and Guttentag (1974) broke the tradition of computing yield with an average life estimate and used the entire distribution of termination probabilities for the appropriate mortgage characteristics. They reported that the effective yield was sensitive to changes in discount points and the unknown prepayment date. With smaller discounts and lower market yields, the borrower had more incentive to refinance. Termination rates rose sharply in early policy years, declined slowly and then jumped sharply as the policy year approached maturity.[19] Curley and Guttentag (1974) noted that mortgages prepaid before the average life had much higher than average yield, but mortgages prepaid after the average life had yields slightly below average.

Assuming stable market yields, Curley and Guttentag (1974) built a regression model of termination rates with an

---

[18] See Swan (1982).

[19] In Curley and Guttentag (1977) this cyclical pattern of termination rates is referred to as a "life cycle pattern."

R-squared of 86.7%. The logarithm of the termination rate was significantly positively related to the policy year relative to maturity and significantly negatively related to the size of the discount, and the excess of the original contract rate over the policy year rate.

Next, Curley and Guttentag (1974) considered foreclosure costs that reduced the realized yield. They assumed that no principal payments were made during settlement, interest was paid two months after the last payment, and legal fees were partially reimbursed to the lender. Curley and Guttentag (1974) calculated a net foreclosure gain or loss (NFGL) for 108 foreclosed FHA mortgages settled in 1967 and 1968. The NFGL ranged from 396 basis points to -101 basis points with about two-thirds of the estimates being losses. In regression models with R-squared values ranging from 40.7% to 80.3%, NFGL was significantly positively related to the duration transformation term,[20] the discount points, and the duration. Significant negative relationships were noted between NFGL and the settlement period, legal expenses, the contract rate-debenture rate differential, and the legal expenses as a percentage of the original loan amount.

Curley and Guttentag (1974) reported a typical equalizing discount (where the yield on the foreclosed loan equalled the expected yield) of 3 to 4.5 points on FHA loans. During the period under study, actual points on the average FHA loan exceeded 4.5 points. This revealed that lenders incorporated potential losses from foreclosure expenses into the original terms of the mortgage contract.

---

[20] Curley and Guttentag (1974) developed the duration transformation term using simulations of hypothetical mortgages. It was a function of the duration in years and the number of discount points.

Curley and Guttentag (1977) ignored the potential impact of borrower default and reinvestment rate assumptions to focus on measuring the magnitude of error in termination rates. Using the life cycle pattern of termination rates identified in Curley and Guttentag (1974), the 1977 study reported pronounced patterns of the true value with their procedure minus the expected value calculated with conventional estimates.

To quantify the yield risk,[21] Curley and Guttentag (1977) estimated the expected yield for varying discounts on new mortgages. When outstanding mortgages were priced at a discount, the difference between the expected and high boundary yields was twice as large as the difference between the expected and low boundary yields. Conversely when outstanding mortgages were priced at a premium, the expected and low boundary yield difference was twice as large as the expected and high boundary difference.

Theoretically, the yield risk could be diversified away by combining discount mortgages with premium mortgages.

---

[21] Curley and Guttentag (1977) defined yield risk as the deviation between estimated and realized termination rates.

Unfortunately, premium mortgages were scarce. Curley and Guttentag (1977) still maintained that effective diversification was possible if their basic model accurately described the determinants of termination rates and if deviations of actual versus expected termination rates were random.

Kaufman and Morgan (1980) presented additional insights for managing prepayment risk. They recognized the varying levels and shapes of the yield curve (and underlying term structure)[22] and corrected the unrealistic Curley and Guttentag (1977) assumption that interim cash flows could be reinvested at the contract rate. They pointed out that the changing yield curve caused a coupon bias in the calculations of mortgage yield[23]. To isolate the analysis, they assumed annual payments, certain prepayment dates, different term structures and computed the coupon bias for mortgages and comparable bonds

Kaufman and Morgan reported that coupon bias depended on the payment timing, security age, and the level of the term structure. A mortgage with an earlier termination date had a smaller coupon bias than a same term non-prepaid mortgage that had more reinvestment risk. Kaufman and Morgan also noted that for mortgages prepaid in later years, a bond of equal maturity and duration was not likely to have comparable coupons. Despite these revelations, mortgage yields calculated with an estimate of average termination age remained the dominant basis of most mortgage contracts and trades. Additional reasons to abandon this approach were studied by Green and Shoven (1986).

---

[22] Kaufman and Morgan (1980) defined (1) the yield curve as a line connecting the yields-to-maturity for all maturities, and (2) the term structure as a line connecting holding period yields for all maturities.

[23] The coupon bias was defined as the difference between the yield-to-maturity and the expected holding period return.

Green and Shoven (1986) observed that between the late 1970s and the early 1980s, the practitioner rule-of-thumb estimate of mortgage termination changed from seven years to twelve years. They attributed the change to a 1978 case--Wellenkamp versus Bank of America--that prohibited the use of due-on-sale clauses for the sole purpose of raising mortgage rates. Green and Shoven estimated the effect of this ruling on prepayment rates and value transferred from lenders to borrowers. They recognized that the prepayment decision was primarily determined by personal circumstances of the owner. By analyzing data on 3,938 individual mortgages[24] held by two California Savings and Loan Associations, they observed nonfinancial motivations for prepayment.

Green and Shoven estimated the probability of turnover at each tenure as a function of the relationship between the market value of the mortgage and its remaining principal balance. They assumed a "baseline hazard" that reflected the proportion of the population that would prepay under stationary conditions.[25] The vector of determinants included the length of tenure in the house, the age of the mortgage, a dummy variable indicating prepaid or non-prepaid, and a proxy for the interest lock-in relative to the "real" initial mortgage amount.[26]

---

[24] Eighty-four percent of the mortgages studied were conventional mortgages, 10 percent were VA mortgages and 6 percent were FHA mortgages.

Green and Shoven observed the set of mortgages originated between 1947 and 1976 and noted that 2,037 of the 3,938 loans paid off between 1975 and 1982. The data was partitioned around the date of the Wellenkamp decision on due-on-sale clauses. Maximum likelihood estimates for the pre-ruling period showed a -4.37 parameter for the interest rate lock-in. The parameter decreased to -13.07 when the Wellenkamp decision was in effect. This result showed that the probability of prepayment decreased when the spread between the contractual rate and the market rate increased. This relationship was stronger when the due-on-sale clause was unenforceable.

Green and Shoven reported high sensitivity of mortgage value to interest rates and to rules about due-on-sale clauses. The average prepayment rates for a 10% mortgage was

---

[25] Green and Shoven (1986) based the proportional hazard function on the presumption that factors affecting turnover were specific to the individual.

[26] To capture the interest rate sensitivity of the probability of payout at a particular age, Green and Shoven (1986) computed the lock-in as the net of the face and market values of the loan divided by the initial principal amount updated by the ratio of the current and initial price index for urban California housing units.

7.331 years when rates rose to 12% and due-on-sale was enforced. When mortgages were assumable, average repayment occurred at 10.337 years. Green and Shoven concluded that this observation justified the increase in the rule-of-thumb estimate of average mortgage life. A 1982 due-on-sale clause case prompted more study of prepayment risk by Anderson and Chiang (1987).

Anderson and Chiang (1987) cited the June 1982 Supreme Court decision on Fidelity Federal Savings and Loan Association, et al. that allowed federally insured savings and loan associations (S&Ls) to enforce due-on-sale clauses in mortgage agreements.[27] After the change, the life of the loan depended on the potential sale date as well as other triggers for prepayment. Protection from reinvestment risk became a more important issue to mortgage lenders

Anderson and Chiang described the traditional approach to eliminate interest rate risk by adding Government National Mortgage Association (GNMA) futures contracts to a portfolio of conventional mortgages. The success of attempts to hedge conventional mortgage portfolios with GNMA futures depended on the prepayment distributions of both conventional mortgages and the FHA and Veterans Administration (VA) mortgages underlying GNMA futures contracts. Although the misspecification errors reported when hedging with GNMA futures are smaller than when hedging with Treasury bill futures, the error with average life was 4.33 times as large as the error with actual life. Lenders who attempted to immunize a portfolio of conventional mortgages using GNMA futures and average mortgage lives were ineffective in protecting themselves from interest rate risk. Other researchers continued the pursuit of prepayment prediction.

---

[27] Later in the same year, the Garn-St. Germain Depository Institution Act afforded the same option to all mortgage lenders.

Quigley and Van Order (1990) examined the exercise of prepayment options as predicted by contingent claim models. Most contingent claim models included an assumption that borrowers prepay when market rates fall below contract rates. Using a variety of hazard models to forecast the conditional probability of prepayment, Quigley and Van Order tested over 6,300 non-assumable, default-free, conventional mortgages issued between 1976 and 1980. The key contribution of their study was the use of a measure of the extent to which the prepayment option was "in the money" as an explanatory variable. The measure was computed by subtracting the par value from the present value of the remaining payments plus the value of the call option and dividing the result by par. This represented the percent savings available by refinancing.

The method of partial likelihood was used to estimate the proportionality of the conditional probability of prepayment hazard relationship. In the 1976-80 market where interest rate varied from 8% to 13%, mortgages with contract rates between 8% and 14% had a percentage savings from prepayment ranging from zero to 51%. These mortgages originated as 30-year, fixed-rate contracts and averaged a prepayment rate of 6% or 7%. Quigley and Van Order found that the extent to which the option was in the money significantly affected the probability of conditional exercise. In other models, they found weak evidence that the initial loan-to-value ratio affected prepayment decisions. For younger mortgages, the probability of prepayment was substantially higher than mortgages with fewer years to maturity.

Without a baseline hazard, they considered the rules-of-thumb used by financial institutions relative to PSA survival rates.[28] They found that the option must be in the money by about 10% before it was exercised rapidly. Also noted was the significant acceleration in prepayments for five-year-old mortgages after rate declines of 150 to 200 basis points below mortgage coupon rates.

Quigley and Van Order recognized a critical interest rate at which prepayment was expected. The effect of property value on the termination (by default or prepayment) of a mortgage was not considered.[29] The analysis ignored not only termination effects, but also transactions costs and the value of the option to prepay at a future date. The remaining studies in this sub-section consider some of these features in the task of valuing the prepayment option.

---

[28] Hutchinson and Zanios (1991) stated that the Public Securities Association (PSA) model expected prepayment rates to increase linearly for the first 30 months of the mortgage until reaching a rate of 6%. The prepayment remained constant thereafter and the level of repayment was independent of current rates.

[29] Kau, Keenan, Muller, and Epperson--KKME (1987) presented a generalized model that identified a region of probable default that fell below a critical property value. Beyond the critical property value, KKME recognized a probable

Buser and Hendershott (1984) simulated values for the prepayment option of various mortgage contracts to test the sensitivity of the call premium to changes in the values of key parameters.[30] Prior studies assigned values of these key parameter estimates.[31] Buser and Hendershott allowed the values to fluctuate and found substantial uncertainty for many parameter values.

Buser and Hendershott assumed the mortgages were fully amortizable and that refinancing would occur when the refinancing wedge equalled the refinancing costs plus the value of the unused option. They assumed zero tax effects and used bond equivalent yields for GNMA pools of graduated and level-payment mortgages. With a measure capturing unexpected changes in interest rates, they showed that the long-run mean and the spot rates were greatly explained by the surprise

---

prepayment region.

[30] The valuation model included parameters for the long-run mean of the process that generates spot interest rates, the speed at which interest rates adjust to mean reverting values, the scale of the standard deviation, the elasticity of the standard deviation with respect to the spot rate of interest, the market price of risk, and the size of the wedge for refinancing costs.

[31] See Dunn and McConnell (1981 a, b) and Cunningham and Hendershott (1984).

proxy. Buser and Hendershott relied on the implicit difference method of Brennan and Schwartz (1977) to estimate the constant-elasticity standard deviation (CES). Their estimates of CES were higher when rates were more volatile, but differences from earlier periods were small

With a zero refinancing wedge assumption and other parameters at Dunn and McConnell base values, they found the value of the call option in 8% coupon GNMAs was most sensitive to the yield on infinite-maturity default-free debt (the proxy for the long-run mean of the process) and the interest rate speed of adjustment. The call value was also sensitive to changes in the magnitude of the scale of the standard deviation and relatively insensitive to changes in the other parameter values. These results were compared to estimates for mortgages in market conditions of early 1984.

When Buser and Hendershott assumed a 3% refinancing wedge with early 1984 parameter values, the estimated call value for 8% coupon GNMAs was triple the value under the Dunn-McConnell assumptions. The option value was most sensitive to the changes in the same parameter values as before. Next, they computed call option values for 13% coupon GNMAs and found that the call premium was less sensitive to changes in parameter values than in the other two cases. Last, they compared the call option value for GNMAs based on 15-year and 30-year level-payment mortgages and 30-year graduated-payment mortgages (GPMs). Buser and Hendershott found that the call premium was insensitive to changes in all parameter values, except at low spot rates when the 15-year call premium was less than the 30-year. In the analysis of 30-year GPMs, different parameter values and spot rates did not alter the call premium.

Buser and Hendershott concluded that the contingent claims methodology was operationally less reliable in the valuation of options on bonds than in the analogous application to stock options.[32] This suggested that such models were more appropriate for comparative valuation of financial securities, but not absolute valuation. Support for these conclusions were provided by Arden Hall.

Hall (1985) used a two-state option pricing model to simulate the value of prepayment options for fixed-rate mortgages (FRMs). Because the property owner also owned the non-transferable prepayment option,[33] maximizing property value would not always maximize option value. Hall suggested that traditional OPMs overvalue the mortgage call option for borrowers with nonfinancial incentives.

By assuming risk neutrality, a fixed prepayment penalty, no arbitrage, dominance, and the existence of a riskless interest rate, Hall estimated the interest rate process using a binary model of interest rate movements assuming path independence of interest rates from one period to the next. He calculated hedge ratios, and uniquely determined the option price and the value of the underlying debt. By varying the mean and standard deviation parameter estimates, Hall estimated the option value and the contract interest rate and found that both measures were sensitive to the choice of parameters. Changes in standard deviation had a much larger impact on value of the prepayment option then changes in the mean. Hall also found that a lender loss more by reducing the penalty than by reducing the prepayment penalty period. He reported that short-termed fully amortized mortgages and mortgages with balloon payments had less valuable prepayment options than long-termed fully amortized mortgages.

---

[32] See Black and Scholes (1972) and Merton (1973).

[33] Most mortgages had due-on-sale clauses that gave the lender the option to put the mortgage to the borrower, when the property was sold.

The studies about valuation of mortgage prepayment revealed that prepayment depended on the borrower's personal situation, mortgage age, discount points, interest rates and foreclosure. Curley and Guttentag (1974) showed that lenders priced foreclosure costs in the original contract. Curley and Guttentag (1977) reported patterns in the measurement error for termination and suggested that the patterns could be used to diversify the lender's interest rate risk. Green and Shoven (1986) introduced nonfinancial incentives and rules on due-on-sale clauses as prepayment motives. Anderson and Chiang (1987) found that using GNMA futures was not an effective means of immunizing a mortgage portfolio. Quigley and Van Order (1990) noted that savings from refinancing motivated prepayment.

Many factors noted in the prepayment studies affected the value of the entire mortgage contract. Buser and Hendershott (1984) concluded that OPMs did not capture all the factors for the valuation of mortgage prepayment. Even so, OPMs and other contingent claim models dominated the literature for the valuation of the entire mortgage contract.

The Valuation of the Entire Mortgage

Dunn and McConnell (1981a) simulated prices for default-free fixed-rate GNMA mortgage-backed securities (MBS) calculated by two yield based models and a contingent claims model. The discrete-time and static yield based prices were generated by two certainty models: (1) the average life procedure that assumed prepayment in the 12th year of a 30 year FHA mortgage contract, and (2) an abbreviated version of the 1974 Curley and Guttentag (CG*) model that assumed the yield-to-maturity was the same for all GNMAs and actual prepayment history produced a more accurate estimate of the conditional probability of prepayment. The continuous-time, dynamic and uncertain contingent claims model[34] assumed that the risk-free interest rate followed a mean reverting stationary Markov process allowing an optimal prepayment policy to exist. Under the optimal prepayment strategy, a mortgagor prepaid the existing loan with an otherwise identical loan at an effective rate of interest below the initial contract rate.

---

[34] Based on Brennan and Schwartz (1977).

Dunn and McConnell (1981a) found that the closer the newly issued security's price was to par, the smaller the price differences between models. They also noted that for longer time to maturity, the prices from the average life model were always less than the prices with the contingent claims model and usually less than the abbreviated CG* prices. For higher prepayment rates, the price differences were larger because the average life procedure did not allow prepayment in early years. When the term structure was flat, all three models generated similar prices. When the term structure was rising, the contingent claims model generated prices greater than the yield based models. When the term structure was falling, the CG* model consistently estimated higher prices. These results reflected the flat term structure assumption inherent in the average life and the CG* models. Except with lower prepayment rate assumptions, the price differences were greater with lower coupon rates.

Dunn and McConnell (1981a) concluded that the contingent claims model was superior because it captured the dynamics of the prepayment option.[35] Because prices were quoted in one thirty-seconds of a dollar and since the GNMA securities were traded in large dollar amounts, a small improvement in the price estimates could be beneficial to dealers and investors in GNMA mortgage-backed securities.

---

[35] Buser and Hendershott (1984) refuted this conclusion.

Dunn and McConnell (1981b) used their 1981a contingent claims pricing model to compute prices of four default-free securities to value the amortization feature, the call option and the prepayment option.[36] The results were used to isolate the effects of security features on returns and risks. The model allowed not only optimal prepayments, but also non-optimal prepayments following a Poisson-driven process.

Optimal call exercise precluded bond prices from exceeding the principal balance. Since perfect markets were assumed and the uncertainty of non-optimal prepayments was unique, this risk could be costlessly diversified away. The value of each security was modeled by a risk-adjustment parameter, a speed of adjustment parameter, and the instantaneous variance of the interest rate. To calculate prices, they assumed an original term of 30 years, an 8% coupon and the instantaneous interest rate was allowed to vary from zero to 20%.

At every rate, the value of the call feature could be computed by subtracting the value of a non-amortizing, callable bond from the value of a non-amortizing, non-callable bond. The call value also could be identified by the value of an amortizing, non-callable bond less the value of a GNMA security with the optimal call policy. Since the value of a callable bond could not exceed its price, the call option value was smaller when the current interest rate rose. Therefore when rates were high, the callable security was less interest rate sensitive. The call feature reduced the expected return and the holder's exposure to interest rate risk. When the time to maturity was distant, the call feature had greater value than the other options.

---

[36] Hendershott and Van Order (1987) described the amortization schedule as the boundary condition that the mortgage had zero value at maturity.

The value of the amortization feature was computed by subtracting the value of an amortizable security from the value of an otherwise identical non-amortizing security. Dunn and McConnell (1981b) reported that the small contribution caused the amortizing bond to be more valuable when current rates were high and the non-amortizing bond to be more valuable when current rates fell below the coupon rate. The amortization feature had the largest impact on value with a short term to maturity.

Suboptimal payments were analyzed by comparing the computed values of GNMA securities with optimal prepayment policies to GNMA values when prepayment was suboptimal. The value of suboptimal prepayment to the holder was greater with larger discounts. Both the interest rate risk and expected return of a GNMA security fell when suboptimal payments were made. Although this unsystematic risk was not compensated, suboptimal prepayment reduced the sensitivity of the price to changes in the interest rates. As the remaining term to maturity declined, the prices for non-callable bonds and callable bonds with optimal call policy declined to an asymptote. Dunn and McConnell (1981b) also found that the value of the GNMA security with suboptimal prepayment decreased rapidly up to 30 years. With a better understanding of mortgage price behavior, researchers began to ponder the relationship between mortgage prices and the prices of U.S. Treasury bonds.

Dunn and Singleton (1983) tested a discrete time, consumption based model of security prices to consider the widely held view that GNMA pass-through securities were "incorrectly" priced relative to long-term U.S. Treasury bonds. Using 8%, fixed-rate, single family concurrent date GNMA securities from February 1972 to June 1978, they computed the monthly cash flows and holding period returns.

In the investigation of the restrictions on prices imposed by intertemporal utility maximization problems under uncertainty, Dunn and Singleton assumed that decision intervals were identical with the data interval (one month), that the consumption growth rates and security returns were stationary in a joint distribution and that unscheduled prepayments were known at the end of each month.[37]

---

[37] Unlike other pricing models that assumed continuous time, Dunn and Singleton (1983) avoided the problem of temporal aggregation and the need to specify the economic

Additionally, consumers were assumed to maximize the expected value of a concave von Naumenn-Morganstern utility function. Their evidence did not support the mispricing theory. It appeared that the restrictions implied by the consumption-based model were appropriate for GNMA securities.

Brennan and Schwartz (1985) compared monthly bond prices from 1958-1979 using three pricing models. Two of the models employed a single-state variable and the authors contributed a two-state model. Brennan and Schwartz (1985) inferred pricing errors between GNMA securities and U.S. Treasury bonds by the alternative models. They reported that assumptions regarding call policy significantly impacted the value estimates.

The short rate model assumed that all default-free security values depended a single stochastic variable--the current short rate. The Black-Scholes-Merton single state model assumptions included that values of securities were a function of the risky nonstochastic instantaneous interest rate and time.[38] The more dynamic Brennan-Schwartz two-interest rate model assumed that all default-free bonds could be valued in terms of a short and a long stochastic interest rate, the coupon rate, the face value of unity, the maturity date, and the market price of risk function. For both the

---

environment.

[38] For other assumptions, see Black and Scholes (1972, 1973) and Merton (1973, 1974)

Black-Scholes-Merton and Brennan-Schwartz models, the underlying asset was a consul bond.

Brennan and Schwartz (1985) found that both of the single-state variable models substantially understate the value of short-term call options on 20-year bonds relative to the two-state model. They further explained that under an optimal call strategy, the GNMA value may fall on either side of the bond value. With high long rates, the GNMA traded at a premium. They attributed this result to the amortizing feature of the GNMA that was not available in the U.S. Treasury bond. The additional uncertainty in the two state model generated a larger value of the call option. The limited conclusiveness of studies on residential mortgage value caused researchers to consider the valuation of commercial mortgages.

Kau, Keenan, Muller and Epperson--KKME (1987) developed a seminal pricing model for commercial mortgages and their mortgage- backed securities (MBS). When compared to the terms of bond contracts, the covenants on commercial mortgages were simple and homogeneous. Less complex than residential mortgages, commercial mortgages were collateralized primarily by buildings financed with only one mortgage. More than half commercial mortgages prohibited prepayment. Because the commercial borrower was expected to be a value maximizer, Titman and Torous (1989) concluded that commercial mortgage default would be financially optimal, and that non-prepayable fixed-rate commercial mortgages isolated the default option value.

KKME (1987) illustrated that the MBS value was passively based on the value of the underlying mortgage. Although the MBS was considered default-free, when the mortgagor defaulted on a mortgage, the issuer of the MBS was legally obligated to prepay to the MBS investor.

The KKME (1987) economic setting employed a standard instantaneous mean reverting interest rate process with building values that incorporated appreciation and the expected rate of return on assets. The commercial mortgage valuation model assumed a 30-year amortization schedule with the unpaid balance as a balloon payment after the 15th year.[39] Assuming perfect capital markets and no real transaction costs, the mortgage value was modeled as a function of uncertain future property values, a continuous term structure of interest rates, the value of the scheduled payments, the value of the prepayment option, and the value of the default option.

KKME (1987) recognized that prepayment could be restricted by a lockout period and deterred by the borrower's downpayment and payment of points. Since prepayment could occur at almost anytime, the value of the prepayment option reflected the lost opportunity for future prepayment.

---

[39] This payment structure was common for commercial mortgages.

KKME (1987) illustrated regions of continuation, default and prepayment that affected the commercial mortgage value as well as the value of its MBS. After the lockout period, graphs of the state space for the securities had a negatively sloped default region. The cost of continuing was lower when interest rates were higher, but at the very lowest property values, the borrower had the incentive to default. Subject to the constraints imposed by prepayment penalties and lockout periods, the prepayment region was upward sloping since prepayment was more likely (than default) when building values were higher and interest rates were low.

The rational borrower maximized personal wealth by minimizing the value of the mortgage in the decision to default or prepay. Prepayment dominated when interest rates were low and default dominated with low property values. Since the cash flows to the MBS holder were identical, the MBS investor was indifferent between termination methods.[40] In comparative static analysis, KKME (1987) found that increases in the volatility of rates and building values increased the value of terminating the mortgage. Movement of rates affected the prepayment option and movement of building values affected the default option. When the value of terminating the mortgage increased, the value of the mortgage fell. In response, the equilibrium contract rate rose to compensate the investor for additional exposure to interest rate risk. When building values fell, KKME (1987) found that the increase in the default option value dominated other effects on mortgage value.

---

[40] For this reason, Kau, Hendershott and Van Order (1987) stated that the investor could have a gain or a loss when the borrower terminated the mortgage contract.

Hendershott and Van Order (1987) suggested that rational default occurred when people reached a zero or negative equity position and for other situations driven by borrower characteristics.[41] The default option had value if the building value fell below the mortgage value and the prepayment option lacked value at the end of the contract or if default occurred.

Hendershott and Van Order (1987) explained that when default and prepayment options were combined in one security, some defaults were avoided because optimal prepayment occurred before rates fell enough for mortgage value to equal the house value (where default would have been optimal). This observation was supported by the KKME (1987) depiction of mortgage termination decisions. Hendershott and Van Order (1987) reported that the lender's mortgage value was the borrow's value minus the refinancing charge (typically paid to another lender). In the presence of both prepayment and refinancing opportunities, there was a range over which falling rates lowered mortgage values.[42] The refinancing charge caused the mortgage value to exceed par, but as rates continued to drop and refinancing became more likely, the mortgage value returned to par.

---

[41] Sandor and Sosin (1975) found that borrower characteristics significantly influenced the mortgage yield spread

[42] In this range, the mortgage had a negative duration.

Theoretically, frictionless markets would preclude mortgage derivatives, pricing models were relaxed to include transactions costs to price agency pass-through securities, collateralized mortgage obligations (CMOs), and mortgage strips. In reality, the presence of trading costs implied that scale economies allowed investment bankers to create derivatives cheaper than individual investors could.[43]

KKME (1987) reported that the MBS value maintained a passive relationship with the mortgage value. MBS terms were specified when the guarantee fee was set. The fee reduced the cash flows to the investor and therefore decreased the value of the MBS. There was a tradeoff between the upfront payment by a MBS investor and the guarantee fee that was paid over the life of the MBS. When building values were volatile, the MBS value increased. These theoretical results reflected complex relationships between the mortgage and MBS values, but the impossibility of closed form solutions precluded empirical tests.[44] Without a party acting rationally to affect MBS values, the MBS had more complicated price behavior than the related mortgage contract. Because of the complexities of residential mortgages, other scholars joined KKMZ by evaluating mortgage valuation models using commercial mortgages.

---

[43] Though not included here, Hendershott and Van Order (1987) discussed the value relationships for mortgage insurance, ARMs, STRIPS and CMOs for interest rate changes.

[44] Only Hall (1985) and Titman and Torous (1989) compared price estimates with market prices.

Titman and Torous (1989) formed and tested a contingent claims model of commercial mortgage values as a function of the instantaneous risk-free rate and the value of the mortgaged building. Combined, the default-free bond, the building, and the mortgage created a risk-free portfolio. They identified the critical building value that made default optimal.

For comparison, Titman and Torous valued the same securities using a naive pricing model that assumed a constant conditional probability of default. Mortgage prices depended on this probability, the total number of promised payments, and the current price of a default-free bond with identical promised payments through the date of default.

Titman and Torous examined rates quoted by six large insurance companies for three-, five-, seven-, and ten-year prepayment-free, commercial bullet mortgages. Using nonlinear least squares procedures, they estimated parameters for the dates that mortgage quotes were available. When the implied long-term default-free rate was low, the model tended to underprice Treasury bonds with three years-to-maturity and overprice bonds with ten years-to-maturity. Since the errors were small, Titman and Torous proceeded with the estimated implied long-term default-free interest rate, instantaneous risk-free interest rate, and their standard deviations.

Titman and Torous generated a plausible range of mortgage rates to test their pricing model. The quoted rates were compared to the computed mortgage rates, which increased substantially as the volatility of the building value rose. The estimated mortgage rates with the lowest volatilities and the lowest payout rates were lower than the observed quotes. Despite the variations between the estimates and quotes, the observed spreads between commercial mortgages and Treasury bonds were reasonably estimated.

The Titman and Torous contingent claims model had a lower mean square pricing error compared to the naive model, which systematically over(under)priced mortgages with three and five (ten) years-to-maturity. They concluded that on average, the contingent claims approach did not systematically misprice the sampled commercial mortgages and was unrelated with the mispricing of the Treasury bonds.

Schwartz and Torous (1989) offered an alternative to prior models[45] that imposed optimal call exercise strategies for borrowers with nonfinancial incentives to prepay mortgages. They assumed a time-independent conditional probability of prepayment depending upon the economy, the mortgage age, and interest cost savings from refinancing for

---

[45] Brennan and Schwartz (1977, 1985), Dunn and McConnell (1981a, b), Kau, Keenan, Muller and Epperson (1987), Titman and Torous (1989).

GNMA 30-year single-family pools from January 1978 to November 1987, they used maximum-likelihood techniques in a proportional-hazards model to estimate a GNMA prepayment function.

The prepayment function was used to extend the two state models employed by Brennan and Schwartz (1985) in a continuous-time model of GNMA mortgage-backed security value. The one-month certificate of deposit rate captured current prepayment incentives. The exponential average of past long-term Treasury bond yields proxied the effects of past refinancing rates on current prepayment decisions. Other variables included the percentage of pools previously prepaid and the mortgage age.[46] The prepayment model identified the cash flows, and the MBS model calculated the present value of the cash flows.

A valuable contribution of Schwartz and Torous was the comparison of MBS valuation models with varying prepayment assumptions. They compared MBS values using their estimated prepayment function to values computed assuming an optimal call policy, using the FHA prepayment experience, and to values for non-prepayable mortgages. They found that MBS values were insensitive to the prevailing short rate, but highly influenced by the prepayment assumption.

---

[46] Seasonality had no significant effect on the probability of prepayment, so it was excluded from the model.

Allowing for both rational and irrational prepayment, the FHA experience model gave more realistic results than the optimal prepayment model. For high long-rates, the value estimates differed greatly--the non-prepayable mortgage consistently had a higher value, followed by the 100% FHA experience, the Schwartz and Torous model and the optimal prepayment. For low long-rates, values were closer, but the FHA prepayment estimated the highest values, the optimal prepayment generated the lowest values and the non-prepayable values were slightly less than the values estimated with the prepayment function. The optimal prepayment models did not capture nonfinancial factors that affected mortgage prepayment decisions. The authors stated that their model provided mortgage prices consistant with the premiums at which MBSs traded.

David Shimko (1989) developed a theoretical contingent claim model to value securities with discrete stochastic expected cash flows generated by a Poisson arrival process. The cash flows had systematic risk, where the timing was independent of the state variables. Cash flow changes were generated by jump and continuous processes with arrival frequencies that were correlated with state variables in the economy. Shimko used the cash flow arrival rate in the set of relevant state values. The arrival intensity of the cash flows was assumed to follow a lognormal diffusion process and the correlation between the interest rate and default rate was assumed to be zero.

Shimko's model made the standard assumptions of an intertemporal general equilibrium model of asset prices. The additional assumptions included the existence of a financial intermediary with many projects generating cash flows by a Poisson arrival process with a widely dispersed ownership of many shareholders owning one share of stock and receiving proportional cash flows. Lastly, Shimko assumed that continuous conditional cash flows followed a Wiener process.

Shimko discussed, but did not test the application of the model to the valuation of a health insurance contract with payments conditional on the incidence of a medical expense, a firm with uncertain future growth opportunities, and a MBS with optimal and autonomous prepayments. The mortgage analysis followed Dunn and McConnell (1981b), Merton (1983), Brennan and Schwartz (1985) and Schwartz and Torous (1989). Many of these concepts were tested empirically in the next study.

O'Keefe and Van Order (1990) ran separate regressions for premium, near par and discount GNMA mortgages, tested for changes in the relationship between prices and their determinants. Default-free[47] and callable GNMA mortgage-backed security prices were modeled as a function of a vector of interest rates, the mortgage age, the maturity date and a vector measuring interest-rate volatility.[48] To restrict the infinite number of solutions to the contingent claim model, O'Keefe and Van Order assumed an optimal call strategy.

---

[47] O'Keefe and Van Order recognized that with the GNMA guarantee to prepay to MBS investors when mortgagors default, the prepayment at par could be important if default risk was large

Using 880 GNMA prices from January 1981 to January 1986 with coupons ranging from 6.5% to 15%, O'Keefe and Van Order had the following findings:

(1) For a 1% increase in rates, premium, par, and discount prices fell by 2.07%, 5.90%, and 6.40%. This reflected lower interest sensitivity for premium priced mortgages.

(2) The 6-month and 10-year rates were negatively significant for all three groups of mortgage prices. However, the 6-month rate seemed more important to the premium priced mortgage than to the par or discounted mortgage. The ten year rate had greater significance in determining mortgage prices than did the 6-month rate.

(3) Volatility decreased mortgage values but had the greatest impact for par values, less for premium prices and a marginal impact for deep discount mortgages.

(4) The impact of CMOs increased the number of investors in the mortgage market and a seemingly permanent positive structural shift was noted around the time of the introduction of the CMO.

Kau, Keenan, Muller and Epperson-- KKME (1992) used a comprehensive OPM to value mortgages and mortgage insurance. Though closely related to the mortgage, the insurance was valued as a separate asset for the lender. KKME (1992) assumed that the nominal value of the house followed a lognormal process and that the return from owning a house came from price appreciation and a service flow that was proportional to the house value. The default-free nominal interest rate followed a mean-reverting process, transactions costs were zero, and insurance premiums were fully paid at origination. They modeled prepayment with the PSA schedule.

---

[48] The equilibrium condition for the pricing function was derived using a standard arbitrage assumption as in Brennan and Schwartz (1985) and Hendershott and Van Order (1987).

KKME (1987, 1992) illustrated a state space of values and rates that showed regions of prepayment, default and continuation. The KKME (1992) distinction was the recognition of personal inducements to terminate like divorce, job changes, retirements, or deaths. KKME (1992) also considered that continuation was rational only if the right to prepay or default in the future was valuable. After balancing combinations of points and contract rates, KKME (1992) depicted the values of six FRMs with various combinations of the default option, the prepayment option or insurance coverage. In the lender's portfolio, an uninsured, non-callable, default-free mortgage was equal to the present value of the amortizing payments and had an increasing linear relationship with the contract rate.

Four of the remaining five combinations had the lender's position increasing in the contract, but the relationship was no longer linear. When the prepayment or default option was introduced, the value of the mortgage to the lender fell by the value of the option. With no insurance and no default risk, the mortgage value would not exceed par. With no insurance and no prepayment risk, the mortgage value was limited by the house value. When an uninsured mortgage had a joint option to default or prepay, the lender's position included the present value of promised payments minus an amount less than the sum of the values of the separate options but greater than either individual option value. Because of the substitutability between the default and prepayment options, the lender's position was lowest with the joint option and no insurance. The only combination that can exceed the value of the home was a non-callable mortgage with an insured default option.

In the sixth combination, the more realistic mortgage with a joint option and insurance had the least predictable behavior. For lower contract rates, the lender's position was increasing in the contract rate, but for higher contract rates, the lender's position declined. Insurance lowered the required contract rate and reduced the prepayment value.

Assigning a base set of values for terms of the mortgage contract and the economic environment, KKME (1992) found no significant difference between a contract insured 25% and a contract insured 100%.[49] They suspected that the typical borrower would have defaulted before the house value fell enough to make more coverage valuable. Default was based on market values, but insurance paid at par and the lender still lost the promised future payments.

---

[49] A guarantee by GNMA would be considered full insurance.

In other tests, KKME (1992) found that disregarding default risk had a small value for small equity contributions and minimal house price movement. However, the mortgage value was seriously biased for large loan-to-value ratios and house price volatilities. With high volatilities, the joint option value increased and the value of the mortgage decreased. The net effect to the lender's position depended on the level of insurance. For lower interest rates, insurance value approached zero and mortgage value was limited to par. At higher interest rates, there was a small chance of prepayment, joint options had negative values due to nonfinancial incentives, and the value of the lender's position rose.

KKME (1992) noted that the marginal impact of prepayment in the presence of default exceeded the marginal impact of default in the presence of prepayment. The substitution effects between prepayment and default suggested that each option had less value in the presence of the other and neither could be properly valued without considering the benefits of the present and future termination.

Summary of Pricing Studies

The pricing studies were numerous and diverse. This section summarizes evidence from the pricing studies that impact this dissertation on the mortgage yield spread.

because both security prices and security rates are affected by market forces and since both reflect the underlying risk of the securities, prices and rates are affected by the similar characteristics from market forces, contract terms, and financial market practices regarding the specific security type.

Although bonds were reasonably priced by OPM, there was evidence that the options on a residential mortgage contract were not appropriately priced by OPMs. Cunningham and Hendershott (1984) noted that mortgage insurance premia valued with OPMs did not approximate the costs of default. Buser and Hendershott (1984) concluded that OPMs did not capture all the factors for the valuation of mortgage prepayment. Given the nonfinancial motives for mortgage termination, it seemed realistic that Brennan and Schwartz (1985) found that mortgage value is affected by prepayment assumptions.

Support for OPMs was found in Dunn and McConnell (1981a) who suggested that OPMs capture non-optimal prepayment. Dunn and McConnell (1981b) recognized that the amortization feature had a distinct impact on the value of the mortgage. Additional support for OPMs was found by Dunn and Singleton (1983) who priced GNMAs[50], and KKMK (1987) who priced commercial mortgages. Titman and Torous (1989) agreed that contingent claims models fairly estimate commercial mortgage value.

---

[50] Even so, Schwartz and Torous (1989) found that the use of FHA experience was a better predictor of MBS prepayment than OPMs.

The conflicting debate regarding the efficacy of OPMs for mortgage valuation was complicated by the presence of joint options--to default or to prepay. KKME (1987, 1992), and Hendershott and Van Order (1987) concluded that the substitution effects of the option to prepay versus the option to default would offset within the mortgage valuation model. On the other hand, O'Keefe and Van Order (1990) found evidence that the mispricing of mortgages and MBSs depended on if the instrument was priced above or below par. This position was supported by Quigley and Van Order (1990) who found that the option must be in the money by about 10% before it was exercised rapidly. Despite the OPM controversy, this dissertation considers the impact of evidence from pricing studies on the mortgage yield spread.

The Relationship Between Prices and Yield Spreads

Most of the pricing studies value bonds and mortgages using models similar to Black and Scholes (1972, 1973) and Merton (1973, 1974) that use option pricing in a continuous time framework. To justify the review of pricing and pricing differential studies in a dissertation about the conventional mortgage yield spread, the following derivation solves mathematically for the relationship between pricing differentials and yield differentials. This helps to infer the impact of conclusions in the pricing studies on this dissertation.

In a discrete time framework with a flat yield curve, the following variable definitions are needed to describe the relationship between prices and yields:

Let P_T = the price on a long-term Treasury bond
P_M = the price on a residential mortgage
M = the face value of the bond at maturity
I = the periodic coupon payment on the bond
R_T = the return to the bond investor
R_M = the return to the mortgage lender
n = the maturity date of both the mortgage and the bond
PMT = the payment that amortizes the mortgage in n periods
t = the current period

Time value of money recognizes the relationship between a bond value and a bond rate as follows:

$$P_T = \sum_{t=1}^{n} \left(\frac{I}{(1 + R_T)^t} \right) + \frac{M}{(1 + R_T)^n} \qquad (2\text{-}1)$$

If the fair price of the mortgage is equal to the sum of the discounted future cash flows, then

$$P_M = \sum_{t=1}^{n} \left(\frac{PMT}{(1 + R_M)^t} \right) \qquad (2\text{-}2)$$

Given (1) and (2), the price differential can be stated as

$$(P_T - P_M) = \left[\sum_{t=1}^{n} \left(\frac{I}{(1 + R_T)^t} \right) + \frac{M}{(1 + R_T)^n} \right] - \sum_{t=1}^{n} \left(\frac{PMT}{(1 + R_M)^t} \right) \qquad (2\text{-}3)$$

Financial theory suggests that security prices and rates incorporate the social sum of all market information about the underlying assets. Additionally, equation (2-1) reveals that the price of the bond is inversely related to the rate on the bond and from (2-2) that the price of the mortgage is inversely related to the rate on the mortgage. The relationship between the price differentials and yield differentials is not clear in (2-1), (2-2), or (2-3), but it can be derived from equation (2-3).

To identify the relationship, the following constraints are imposed upon the multi-period discrete time models:

> 1.) The price differential is non-zero. Although it is feasible to find a mortgage with a price equal to a bond price, the non-zero value is necessary to identify the theoretical relationship between a price differential and a rate differential.
>
> 2.) The yield differential is non-zero. Typically, the mortgage rate will be higher than the Treasury rate to compensate the investor for greater default, prepayment, and liquidity risk.
>
> 3.) The cash flows are different. The bond pays interest every period and principal at maturity. The mortgage is amortized by an equal payment composed of a decreasing portion of interest and an increasing portion of repayment of principal.

The third constraint is relaxed below to derive the mathematical relationship between the price differential and the rate differential.

If equation (2-3) is evaluated in the last period and allow the sum of the last period cash flows of the bond (the last interest payment plus the face value) to equal the mortgage payment (a small portion of which is interest and the majority represents repayment of principal), then the price differential between bonds and mortgages can be restated as

$$(P_T - P_M) = \left[\frac{PMT}{(1 + R_T)}\right] - \left[\frac{PMT}{(1 + R_M)}\right] \tag{2-4}$$

To rearrange equation (2-4) to isolate the yield differential in terms of the price differential, divide both sides of (2-4) by PMT:

$$\frac{(P_T - P_M)}{(PMT)} = \left[\frac{1}{(1 + R_T)}\right] - \left[\frac{1}{(1 + R_M)}\right] \tag{2-5}$$

Multiply (2-5) by the common denominator $(1+R_T)(1+R_M)$:

$$\frac{(1+R_T)(1+R_M)(P_T - P_M)}{(PMT)} = \left[\frac{(1+R_T)(1+R_M)}{(1+R_T)}\right] - \left[\frac{(1+R_T)(1+R_M)}{(1+R_M)}\right] \tag{2-6}$$

Cancel common terms on right hand side of equation (2-6):

$$\frac{(1+R_T)(1+R_M)(P_T - P_M)}{(PMT)} = (1+R_M) - (1+R_T) \tag{2-7}$$

Group common terms on right hand side of (2-7) to isolate the yield differential.

$$\frac{(1+R_T)(1+R_M)(P_T - P_M)}{(PMT)} = (R_M - R_T) \tag{2-8}$$

Equation (2-8) gives the relationship between the mortgage yield spread and the price differential. The right hand side of equation (2-8) is expected to be positive because the mortgage rate compensates for additional prepayment, default, and liquidity risk that is not present in the safer, lower yielding Treasury bond. Since interest rates and payments are positive, the sign of the left hand side is determined by the price differential. In order for equation (2-8) to hold P_T must be greater than P_M. This outcome is reasonable since a rational investor would be willing to pay more for a less risky security. In a static analysis, there seems a direct relationship between the price and the rate differentials where for every $1 change in the price differential, there will be the following change in the rate differential:

$$\frac{(1+R_T)(1+R_M)}{(PMT)} \qquad (2-9)$$

The problem with applying equation (2-8) empirically is that the market forces that affect R_M are also likely to simultaneously change the values of R_T, P_M, and P_T. Given the dynamic relationship between rates and prices, the reaction of the spread to price changes would be indeterminant, a priori.

The Determinants of Interest Rates Spreads

This dissertation examines the determinants of the mortgage yield spread. As in the preceding review of pricing studies, this review recognizes that the bond literature provided early evidence of the determinants of interest rate spreads. This review first highlights a few of the articles that examined bond yield spreads and then discusses studies that focus on the mortgage yield spread. This dissertation expands on the lessons learned in both areas.

The Determinants of Bond Yield Spreads

Fisher (1959) defined the risk premium as the net of the market yield-to-maturity on a bond and the corresponding pure rate of interest.[51] Using cross-sectional data on industrial corporations in 1927, 1932, 1937, 1949, and 1953, he accounted for approximately three-fourths of the variance in the logarithm of the risk premium. In a linear function, the determinants included the logarithm of earnings variability, period of solvency, equity to debt ratio, and market value of bonds outstanding. The parameters reflected elasticities of the risk premium with respect to the independent variables.

Fisher found a positive relationship with earnings variability. He reported negative relationships between the risk premium and the period of solvency, the equity to debt ratio, and the market value of the bonds outstanding. The parameter estimates in the model were significant and stable when the level of the risk premium was allowed to vary.

Fisher provided empirical evidence that interest rates include a premium to compensate bondholders for default risk and low marketability of bond securities. Additional comparisons between risky bonds isolated premia for other features in corporate bond contracts in a 1971 study by Fair and Malkiel.

Fair and Malkiel (1971) analyzed bond yield spreads for high quality utility, industrial, and long-term U.S. Treasury bonds. Despite similar ratings, the yield differentials indicated that the three bonds were not perfect substitutes.

---

[51] The pure rate of interest was defined as the rate on a riskless bond having the same maturity date.

In linear systems of equations, Fair and Malkiel modeled the relationships for asset demand and yield differentials. The asset demand equation system showed that the demand for each bond was explained by the yield spreads and wealth stock. If an increase in total wealth was distributed equally among the bonds, a change in the representative yield on other assets had the same effect on all three bonds, that own demand was influenced by other bond rates equally, and that the own supplies were exogenous.[52] Fair and Malkiel described the two-way yield differentials between each bond type as a function of the supply differentials.

With monthly data from January 1961 to June 1969, regression results revealed that yield differentials were significantly influenced by stock differentials. A visible-supply was found to significantly impact the differentials for utility versus government yields, but not for the industrial versus government and industrial versus utility spreads.

The next study considered not only the differential supply effects, but also the callability and default risk of bonds.

Ferri (1978) studied yield differentials for good credit quality seasoned bonds issued by industrial firms, public utilities, and U.S. Government bonds of similar term and taxability. Ferri tested for the effects of default risk, stock differentials, and callability on the yield spreads. The model assumed the outstanding stock of each bond type was fixed, the supply of each bond type was exogenous, and that the Fair and Malkiel (1971) assumptions about the closure and symmetry of the system of equations held.

---

[52] Fair and Malkiel (1971) admitted that to the extent that the supplies were not exogenous, the estimates suffered from simultaneous equation bias.

Three variables were used to proxy for investor estimates of the probability of default: (1) the market value of new orders for durable goods--NO, (2) the Standard & Poor's 500 Stock Index dividend yield--DY, and (3) the Composite Index of Leading Indicators--ILI. For data from 1957 to 1969, Ferri validated the importance of default risk to the industrial-government spread with parameter estimates showing the expected sign at statistically significant levels. In tests of the utility-government differential, DY was the only significant default risk proxy. None of the default risk proxies were significantly related to the industrial-utility yield spread. From 1969 to 1975, the coefficients of the default risk variables were higher and more were significant after major changes in economic conditions in the late sixties. The industrial-utility spread was still not significantly related to the default risk variables.

From 1957-1969, the industrial-government stock differentials had significant impact upon the related spread. When DY was used, the utility-government spread and the industrial-utility spread were significantly related to their stock differentials. When ILI was used, the industrial-utility spread was highly significantly related to the industrial-utility stock differential. After 1969, differences in outstanding stocks continued to influence industrial-government and utility-government yield spreads However, the industrial-utility yield spread was no longer affected by changes in relative supply.

From 1957-1969, Ferri measured the call premium by the difference between the yield on immediately callable, newly distributed, Aa-rated utility bonds and the yield on bonds that have a five year call deferment, but were otherwise identical. This measure was available from Salomon Brothers during that period. For the 1969-1975 period when the measure was unavailable, Ferri used the ninety-day Treasury bill rate to represent the expected movement in future long-term rates.

In both periods, Ferri reported that the proxies for call risk were significant and had the expected relationship to the yield differentials. The magnitude of the parameters reflected that industrial bonds had less call protection than government bonds and more than utility bonds. Ferri concluded that the three bond classes were insufficiently similar to be close substitutes in the early period, but investors began to view utilities and industrials as increasingly close substitutes in the 1970s. Similar inter-market bond yield spreads were investigated in more detail in the next study.

Lamy and Thompson (1988) set up bond pricing models to explain a relative yield spread and an absolute yield spread.

They computed the relative yield spread by taking the difference between the yield on an issue minus the yield on a comparable maturity index and dividing that difference by the yield on the index. The relative yield spread assumed that risk premia were priced relative to the general level of interest rates. Many studies adopted U.S. Treasury bond yields as the index for comparison.[53] Similarly, Lamy and Thompson used the Treasury yield and observed that many investment bankers price primary debt using a Treasury yield as a benchmark. Treasury securities were a precise index since it was easier to match maturities between Treasury issues and other securities.

Lamy and Thompson showed that with either the absolute yield or the relative yield specification, the structural coefficients could be stated as a function of interest rates. They designed two tests to measure the structural stability of the estimated coefficients in the alternative specifications.

In regression estimates, the absolute yield spreads and the relative yield spreads for 392 investment quality issues were regressed against determinants found to be significant in previous empirical research. Lamy and Thompson found the absolute yield spread was significantly positively related to interest rate volatility, and the presence of a sinking fund or a call feature.[54] The absolute yield spread was narrower for higher investment ratings and significantly negatively related to the natural log of the size of the issue. Nonsignificant relationships were noted with the level of interest rates[55] and the Federal Reserve Bank (FRB) change of October 6, 1979[56]. The relative yield spread regression estimates were very similar. The one glaring difference was the high significance of the FRB change variable in the relative yield regression results. This deficiency in the absolute yield specification was exacerbated when Lamy and Thompson observed that all the upper quartile observations occurred after October 1979 and all the lower quartile observations occurred before that date.

---

[53] Fisher (1959), Fair and Malkiel (1971), and Ferri (1978) used Treasury rates in absolute yield spreads.

To isolate interest volatility effects, Lamy and Thompson evaluated the top and bottom quartiles of observations. The partitions were established by identifying the yield of the U.S. Treasury index on days that the bonds in the sample were sold and comparing the yields to the mean value. The upper quartile yields that fell above the mean and the lower quartile yields that fell below the mean were evaluated in models expanded to include interactive terms between each independent variable and a quartile dummy variable. The quartile dummy variable had a value of one if the yield tested was from the upper quartile and zero otherwise.

---

[54] The call variable is measured by the years-to-call or first refunding divided by the years-to-maturity.

[55] The level of interest rates variable was required in the absolute model to account for the effects of interest rate levels. This factor was considered in the dependent variable for the relative model.

[56] On October 6, 1979, the Federal Reserve procedures ceased to offset most disturbances affecting the reserves and the federal funds rate was allowed to fluctuate.

By estimating coefficients for the 195 observations in the two extreme quartiles, Lamy and Thompson tested stability of risk premia over the thirteen plus years in the observation period. The most revealing result was that the determinants measuring the interaction with default risk variables were each significant with the absolute specification and nonsignificant with the relative specification. This showed that the structural coefficients of the default risk proxies in the absolute equation were not stable over the interest rate cycle. When rates were high, the default proxies were significant, when rates were low, the same proxies were nonsignificant. They concluded that the relative measure was a more appropriate specification for yields on primary market bonds because it captured the effects of the FRB change and had stable parameter estimates.

Summary of Bond Yield Spread Studies

In this section, bond yield spread studies reported various measures of the call, default and marketability features in a bond contract. Fisher (1959) showed that investors wanted compensation for their exposure to default and liquidity risk. Fair and Malkiel (1971) offered additional confirmation of the importance of marketability.

Ferri (1978) documented the significance of not only default and liquidity, but also callability. Finally, Lamy and Thompson (1988) found the liquidity premium to be a significant determinant of relative yield spreads and absolute yield spreads for high and low levels of interest rates. These results provided evidence that investors demanded compensation when call, default, or liquidity risk was present in corporate bond contracts.

This dissertation furnishes evidence of the effects of call, default, and liquidity risk on both the absolute and the relative mortgage yield spread. The next sub-section reviews studies of the determinants of mortgage interest rates and various mortgage yield spreads.

The Determinants of Mortgage Yield Spreads

Sandor and Sosin (1975) studied mortgage spreads to develop a model for mortgage default risk premia charged by north California's Citizens Savings and Loan Association on conventional mortgages issued from 1967 to 1971 for owner-occupied single-family homes. The net of the effective mortgage contract rate and the effective prime rate on the loan date compensated Citizens for the extra risk of the mortgage over a loan made to a low risk customer.

Sandor and Sosin examined the pricing policy and the costs of lending to different classes of borrowers using property and borrower characteristics. They found that the mortgage risk premium was significantly positively related to the loan-to-appraisal ratio, the presence of secondary financing, and a fair property condition. The loan term and a good or excellent neighborhood rating were significantly negatively related to the mortgage risk premium. The ratio of monthly housing expense to monthly income, a fair neighborhood rating, the loan amount, a good property rating and an excellent property rating were not significant.

Sandor and Sosin stated that the Citizen priced the mortgage portfolio by funding better quality property and charging higher rates to borrowers with secondary financing, high debt ratios, and high loan-to-appraisal ratios. The lower rates for longer terms and larger loan amounts reflected a policy of lending more money for longer periods to high quality borrowers. The interest rates for securities reflected the risk of the related assets and individuals.

The next study considered the yield spread between GNMA securities and AAA bonds.

Haney (1978) evaluated the yield spread between GNMA pass-through securities and AAA corporate bonds from 1971 to 1976. Although the first GNMA was guaranteed on February 19, 1970, the yields were not available until a year later. GNMAs were issued by FHA-approved mortgagees and backed by the full faith and credit of the U.S. Government. This enabled the investor to transfer legal and administrative problems to the issuer and the default risk to the guarantor.

Because corporate managers compared the relative yields on securities, Haney constructed a model that explained the GNMA-AAA spread in terms of differences in duration, callability, default, marketability, and taxation.[57] The duration considered how the two securities reacted to inflation and changes in interest rates. He assumed that the bond marketability, callability, and taxation risk was constant and that GNMA lacked default risk. Haney found that the GNMA-AAA spread increased with increases in duration, GNMA callability, corporate default, and GNMA marketability.

At the time of Haney's study, S&Ls sheltered net income from taxes by maintaining a certain portion of their assets in "qualified real estate assets"--including GNMAs. This enabled S&Ls to pay a premium price for GNMAs and still receive competitive after-tax yields. S&Ls were important to the acceptance of GNMAs and the use of GNMAs helped to immunize S&L portfolios. When cash flow was high, S&Ls invested in GNMAs that could be easily liquidated when cash flows were low. Using two measures, he found significant offsetting effects for the tax treatment of GNMA revenue to S&Ls. The significantly positive tax effect was with the portion of outstanding GNMAs held by S&Ls. The significantly negative tax effect was measured by a dummy variable that captured the GNMA market reaction to the initial loss of S&Ls

---

[57] Haney uses a bond-adjusted yield for the GNMA yield. This adjustment follows the 12-year average life convention and recognizes monthly interest payments.

when disintermediation caused funds to flow from S&Ls to commercial banks.

A deficiency of Haney was the assumption that default of mortgages lacked affect on the GNMA investor. Though the investor was insured payment on a GNMA when the underlying mortgage defaulted, the payment was before maturity. From the GNMA investor's point of view, mortgage default increased the occurrence of prepayment and therefore increased the investor's exposure to interest rate risk. Additionally, the use of a 12-year prepayment assumption when the average life of GNMAs was lower caused the duration of GNMAs to be overestimated. More evidence of behaviors of GNMA mortgage yield spreads was presented in the following study

Black, Garbade, and Silber--BGS (1981) directly tested the liquidity premium in mortgage yield spreads. They recognized that the FHA-Treasury yield spread compensated investors for exposure to reinvestment risk, market risk, marketability risk, prepayment risk, credit risk, and servicing costs.[58] They defined "timing risk" as the combination of reinvestment and market risks that cause uncertainty in the cash flows on a mortgage. By focusing on the emergence of the GNMA pass-through program, BGS examined the secondary mortgage market impact on the cost of funds for FHA mortgages from 1971 to 1978.

---

[58] Servicing costs were set to 50 basis points before January 1975 and to 37.5 basis points thereafter.

BGS partitioned the FHA-Treasury yield spread, into two component spreads: the FHA-GNMA yield spread and the GNMA-Treasury yield spread. They suggested that FHA-GNMA compensated for the credit risk, marketability risk and servicing costs borne by FHA mortgage holders and that the timing risk for GNMA securities would be identical with the FHA whole mortgages. The GNMA-Treasury yield spread reflected the GNMA holder's demand to be compensated for timing and marketability risks of GNMA cash flows. GNMAs and FHAs were considered substitutes, so an improvement in the marketability of GNMAs would increase investor demand for GNMAs and decrease investor demand for FHAs.

The relative yield spread[59] for GNMA-Treasury was modeled as a function of the marketability of GNMAs. Regression results from monthly data confirmed the anticipated significant negative relationship between the GNMA-Treasury spreads and the marketability of GNMAs as measured by lagged volume of GNMA securities outstanding. BGS used a log likelihood test statistic and found support for the joint hypotheses that the GNMA-Treasury spread was independent of credit risk, servicing costs and the FHA ceiling. They found a positive relationship between the FHA-GNMA yield spread and servicing costs, credit risk (as measured by the net of BAA and AAA bond rates) and higher levels of the FHA ceiling rate. The ceiling lacked affect on yields when it was set within 75 basis points below the FHA yield. It appeared that the FHA-GNMA spread was unrelated to the marketability of GNMAs. Therefore, all marketability effects of the FHA-Treasury spread occurred in the GNMA-Treasury component.

---

[59] The relative yield spread was studied by Lamy and Thompson (1988) who compared results to absolute spread measures and found that the relative yield spread provided more stable parameter estimates for primary market bonds.

The impact of the GNMA program was a reduction in the cost of funds for FHA mortgages. BGS found that FHA yields fell by .0192 times the Treasury yield per $10 billion of GNMA volume. This showed that investors valued the improved marketability of GNMAs as a funding source for FHA mortgages.

Hendershott, Shilling, and Villani--HSV (1983) provided further insights regarding secondary mortgage yield spreads. In an analysis of yield spreads for three mortgage instruments, HSV compared computed yield spreads to quoted yield spreads to identify reasons for disparity. The mortgage instruments evaluated were GNMA pass-throughs, FHLMC participation certificates (PCs), and conventional mortgage commitments. As in prior studies[60], the quoted yields were based on the rule-of-thumb estimates of average termination dates.

HSV posited that the mortgage-Treasury yield spreads would compensate mortgage investors for: losses due to adverse refinancings, assumptions, or defaults, additional tax burden from investment in mortgages, origination costs, and market inefficiencies. They adjusted for the monthly payments on mortgages and semi-annual payments on Treasury securities as well as for expected early terminations.[61]

---

[60] See Curley and Guttentag (1974, 1977), and Kaufman and Morgan (1980)

HSV reported that from 1974 to 1982, the quoted GNMA-Treasury and FHLMC-Treasury spreads were understated relative to the respective calculated yields. For the conventional-Treasury spreads, the quoted series exceeded the computed series during most of the period. The results were insensitive to assumptions regarding expected terminations.

When the quoted spread rose, the amount of the rise understated the rise in the computed spread by a consistent 30-40 basis points for all three mortgage contracts. HSV attributed this pattern to shifts in the level and slope of the yield curve. The effect of the failure to adjust quoted rates for different frequencies in payments had a greater effect if mortgages were not trading at par or the yield curve was not flat. HSV showed that the compounding error accounted for nearly half the understatement for GNMAs and FHLMCs and more than the entire understatement for conventional mortgages. The balance of the GNMA difference was explained by the prepayment assumptions underlying the quoted yields.

Milonas (1987) compared alternative mortgage pricing models after acknowledging that OPMs overestimated the value of the prepayment option by assuming an optimal call policy. With the rise in mobility and divorce, there were nonfinancial motives for the termination of a mortgage. Suggesting that the option was priced in conjunction with other provisions, Milonas employed real estate variables and interest rates to explain the GNMA spread over Treasury bond rates.

---

[61] This adjusted for the coupon bias noted in Kaufman and Morgan (1980).

Milonas contrasted the OPMs[62] with linear regression models.[63] He noted that the OPMs assumed the mortgagors optimally exercised the prepayment option. This was unlikely in the presence of nonfinancial motives, refinancing and other transactions costs were positive. Additionally, OPMs ignored that mortgagors own the option and the property and that decisions they made to maximize the property value might not necessarily maximize the option value. Brennan and Schwartz (1977) added suboptimal prepayments and Brennan and Schwartz (1985) stressed callability as an important feature in OPMs that correctly price GNMAs. Hall (1985) used a mean-variance two-state process of interest rates to price the prepayment option separately from the debt instrument.

The linear models included Curley and Guttentag (1974) who ignored uncertainty as they estimated the probability of prepayment using FHA actuarial data. BGS (1981) recognized that the GNMA-TREAS spread was due to timing risk of unanticipated prepayments and marketability risk when prepayments were late.

---

[62] Dunn and McConnell (1981a,b) Brennan and Schwartz (1977, 1985) and Hall (1985).

[63] Curley and Guttentag (1974), Black, Garbade, and Silber (1981).

Holding constant the impact of social changes on the value of the prepayment option, the Milonas model was tested using monthly data from 1971 to 1985. He compared an average spread of 140 basis points to the BGS (1981) figure of 107.[64] Milonas found that the level of interest rates and the spread between 10-year and 3-month Treasury securities were significantly negatively related to the GNMA-TREAS spread at the 1% level. A significant positive relationship was noted with the FHA yield. Relationships with housing starts, GNMA applications and GNMAs issued were only significant at the 10% level. When Milonas partitioned the data around the October 1979 FRB decision to stop monitoring the money supply to effect interest rates, he found that interest rate volatility increased after the FRB decision.

Edmister and Merriken (1988) investigated the pricing efficiency in the mortgage market for various original mortgage contracts issued by 343 institutions with ample quotes of competitive terms every week for 60 or more consecutive weeks--totalling 39,937 quotes. The lenders were classified as commercial banks, S&Ls institutions, savings banks and mortgage banks. The mortgage contracts evaluated included:

---

[64] The data in this dissertation have an average GNMA-Treasury spread of 121.5 from 1974 to 1990.

> Adjustable-rate conventional mortgages with 1, 2, 3, 5, and 10-year adjustment periods, fixed-rate conventional mortgages with 15, 10, 25, and 30-year maturities, and fixed-rate FHA or VA insured mortgages with 30-year maturities. (Edmister and Merriken, 1988, 52.)

Using traditional serial covariance measures and nonlinear specifications of the mortgage spread over the U.S. Treasury bond yield, they tested ten types of mortgages for four types of lenders. With weekly yield spreads from June 1981 to October 1982, Edmister and Merriken consistently found that the mortgage market was efficient in the weak and semistrong-form definition of efficient markets.[65] By examining 26 instrument-institution combinations, many yields were found to have highly significant autocorrelations providing evidence of possible weak-form inefficiencies. However, Edmister and Merriken also found the 10-year adjustable and the 30-year government-insured mortgages were highly efficient sectors that adjusted fully and immediately regardless of the institution. The speed of rate adjustments varied by contract type rather than by institution.

The nonlinear model of the continuously compounded mortgage-bond spread included determinants for contract terms, the presence or absence of private or government insurance, institutional factors, and mortgage rate adjustments. The loan-to-value ratio was used to represent contract terms and default risk. In relation to the yield spread, Edmister and Merriken found the loan-to-value ratio to be nonsignificant for government insured loans, but highly significant for conventional loans. In the presence of private insurance, the loan-to-value ratio became a significant determinant of the mortgage-bond spread. Another expected outcome was that insured mortgages had lower default premia than uninsured mortgages.

---

[65] Livingston (1990) defined weak-form efficiency as when past price and volume of trading information were instantaneously incorporated into current market prices. Semistrong-form efficiency stated that nonprice information instantaneously impacted current prices, and strong-form efficient prices reflected private information available to special groups of investors.

Edmister and Merriken found that the coefficient of the mortgage banker indicator variable was lower than the coefficients of the indicator variables for commercial banks and thrifts.[66] It seemed that the depository institutions received a premium for providing intermediation services. Besides evidence of mortgage market efficiency, Edmister and Merriken revealed that the presence of mortgage insurance made contract terms for default risk a more meaningful determinant of the mortgage-bond yield spread.

Hendershott and Van Order (1989) stated that mortgage markets became completely integrated into the capital markets in the 1980's. They showed how the market imperfections[67] before the 1970's caused excess accumulation of housing stock and tested how the growth in mortgage pass-through securities altered the relationship between conventional mortgage rates and Treasury rates.

---

[66] Initially, S&Ls and savings banks had identical coefficients, so they were combined into a thrift variable.

[67] The imperfections in the market included ceilings on interest rates for deposits and government subsidized mortgages as well as favorable tax treatment to encourage S&Ls to offer real estate loans.

Assuming perfect mortgage markets, Hendershott and Van Order (1989) developed a model of GNMA prices. Using weekly price and coupon data, they described the GNMA price as a function of interest rate levels, the slope of the term structure, coupon rates, and the volatility of interest rates. With the perfect-market price, Hendershott and Van Order (1989) backed into a perfect-market interest rate. They ran regressions of the retail conventional commitment rates on current and lagged values of the implied perfect-market rate. The percentage of changes in the GNMA rate reflected instantaneously in the conventional rate was close to zero in the 1970's, grew to 8% between 1980 and 1982, doubled to 16% from 1983 to 1985, and swelled to 59% from 1986 to 1989. In the later years of the study, the rapid absorption rates reflected the responsiveness of mortgage rates and the lower liquidity premium required by mortgage investors.

The growth in the secondary mortgage market was constrained by institutional factors and legal requirements. One such limitation was the conforming limit for the maximum size of mortgage allowed in a securitized pool. To regulate the number of conventional FRMs that were pooled by the Federal National Mortgage Association (FNMA) and FHLMC, the agencies were allowed to include only mortgages below a specified conforming limit.

Hendershott and Shilling (1988) reported that the share of new conforming conventional FRMs that were pooled jumped from 5% to 50% in the early 1980s. They tested the significance of the conforming limit to measure the impact that federal agencies had on the yields of FRMs. They examined 4,750 fixed-rate residential loans issued in May-July of 1978 and 1,875 issued in the same months in 1986. To eliminate second mortgages, only mortgages with loan-to value ratios above 70% and with less than 25 years-to-maturity were used. To reduce the impact of regional and institutional differences, Hendershott and Shilling evaluated only mortgages issued by California S&Ls.

Hendershott and Shilling found that the effective rates[68] declined with loan size but jumped as the loan amount reached the limit. For both 1978 and 1986, the Ordinary Least Squares (OLS) regression estimates of the effective loan rate revealed a negative relationship with the real loan size for new loans, and for loans at or under the conforming limit. Effective rates were high for higher loan-to-value ratios The parameter for the conforming loan limit was -5 basis points in 1978 and -29 basis points in 1986. The growth in agency mortgage securitization seemed to have lowered effective yields on conforming loans by 24 basis points relative to jumbo loan yields.[69] When examining rates on loans closed in 1985, Hendershott and Shilling found the conforming loan-rate had little impact. They concluded that 1986 was the first year that the agency influence on FRM rates was significant.

---

[68] Effective rates were calculated assuming a 10-year mortgage life.

Rothberg, Nothaft, and Gabriel--RNG (1989) offered a comprehensive analysis of relative yield spreads between agency pass-through and Treasury securities. The spread compensated the MBS investor for less favorable tax treatment and greater cost of servicing monthly cash flows compared to the semiannual frequency for Treasury obligations. Additional differences in the two rates were due to imbalances in supply and demand, and compensation for default, liquidity and prepayment risk.

The literature often described GNMA securities as default-free because GNMA provided a full U.S. guarantee of timely payment of interest and principal. When the borrower defaulted, the investor only loss if the repayment at par fell below the current market value of the mortgage. Although not known a priori, the investor would have been better off selling the contract one day before default. FHLMC and FNMA securities have slightly greater credit risk than GNMAs because their corporate agency guaranties were not backed by the full faith and credit of the U.S. government.

---

[69] When Hendershott and Shilling (1989) changed the dependent variable to the contract rate, the direction of the parameters remained the same, but the R-squared for the regressions improved slightly. This finding supported Curley and Guttentag (1974, 1977), Kaufman and Morgan (1980), Hendershott, Shilling and Villani (1983), Green and Shoven (1986), and Anderson and Chiang (1987) by identifying deficiencies in the rule-of-thumb measures of mortgage yields.

RNG cited studies that described mortgage prepayment risk in terms of OPMs. Since many popular models did not have closed-form solutions, simulation models were used to value the option features for both GNMA and FHLMC securities. These models also assumed perfect capital markets that would eliminate the motivation for derivative securities.[70]

The liquidity risk between mortgage and Treasury securities was assumed to be constant in the later years of the study. RNG cited BGS (1981), who found that the GNMA-Treasury yield spreads were sensitive to the expansion of the GNMA market during the 1971-1978 period. The question of substitutability determined the effect the supply of pass-through securities would have on mortgage yield spreads. If substitutable with elastic demand, downward price movement from supply increases would be offset as investors liquidated Treasury holdings and purchased MBS. If not perfect substitutes, then growth in MBS volume would have temporarily depressed prices and increased MBS yield spreads over Treasuries.

---

[70] Hendershott and Van Order (1987) suggested that scale economies allowed investment bankers to create mortgage-backed securities cheaper than individual investors could.

Using Cochrane-Orcutt corrections for regressions, the relative GNMA-Treasury spread was explained by interest-rate volatility[71], the slope of the yield curve, and the relative new supply of GNMAs[72]. Similar models included a CMO binary dummy variable and various measures for the liquidity premium. RNG found that the call option measures (the volatility and term structure variables) were highly significant and supported the expectation that prepayments would increase after 1982. Although the new supply variable was always nonsignificant, the other liquidity measures were only significant when the earlier (1971-1974) periods were included. This suggested that by the end of the study (1987), that GNMAs were highly liquid and the spread no longer compensated for marketability risk of GNMAs.

The relative FHLMC-Treasury yield spread was modeled by interest-rate volatility, the slope of the yield curve, the relative new supply of FHLMC PCs, default risk, and the CMO dummy. They found that conventional MBS were more sensitive to prepayment measures. They explained this outcome since then FHA and VA mortgages backing GNMAs were assumable and less likely to prepay. The default measures[73] were only significant when a one month rate volatility was used.

---

[71] This variable was measured by the annualized standard deviation of the log differences in daily yields on ten-year Treasury. It assumed that market expectations of interest-rate volatility were based on recent experience.

[72] RNG treated MBS issuance as exogenously determined by the volume of mortgage origination in the primary mortgage market and measured new supply by the percentage of the current balance issued in the current period.

Ryding (1990) presented a model that included changes in instruments, usury laws, and the three major premia evaluated in this literature review--the prepayment premium, the default premium and the liquidity premium. Ryding investigated the extent to which deregulation of deposit interest rates and innovation of new mortgage contracts have changed the responsiveness of housing investment to monetary policy shifts. Using quarterly data from 1965 to 1988, he concluded that housing investment had become much less sensitive to a rise in the federal funds rate due to elimination of deposit rate ceilings.

Ryding also tested the effect of prepayment risk, default risk, securitization, deregulation, and the introduction of the adjustable-rate mortgage on the mortgage yield spread. He defined the mortgage yield spread as the effective mortgage rates on all conventional home loans closed (fixed and adjustable) minus the weighted average interest rate on Treasury securities. The weighted average combined the ten-year constant maturity Treasury rate and the three-month Treasury bill rate, where the bill rate was given the weight of adjustable-rate mortgages (ARMs) in new loans closed after 1982, when ARM volume became significant.

---

[73] Default risk was measured by the spread between the Moody's composite yields on corporate A and AAA bonds. RNG cite other studies that use similar measures of default because they reflected confidence in the economy.

Using the spread on AAA corporate bonds over Treasury yields as a proxy for default and prepayment risks, Ryding indicated that for each 100 basis points that the spread on corporate bonds widened, the mortgage spread widened by 82.6 basis points. For every percentage of mortgages that was securitized, the spread on mortgages over Treasury rates fell by 3.5 basis points. The abolition of usury ceilings resulted in a small and insignificant reduction of the mortgage yield spread. With the introduction of ARMs, the mortgage yield spread increased by 1.3 basis points. The adjusted-R^2 was 79.7% when the dependent variable used the change in the mortgage interest rate and 96.5% when the level of mortgage rates was used.

Ryding provided a linear model that isolated the liquidity premium in mortgage interest rates. The volume of securitized mortgages reflected growth in the secondary mortgage market that generated a source of funds for mortgage lending that was not available before 1970. The MBS market separated the functions of mortgage lending. The entity with the comparative advantage at performing particular functions gravitated toward a specialized task. Not only were the responsibilities separated, but securitization also provided a vehicle for the efficient pricing of the risks of mortgage cash flows. The liquidity risk was reduced and investors were allowed to choose the cash flow stream that suited their preferences.

Alternative Analysis--Option Adjusted Spread

Recent innovations in the study of mortgage spreads have introduced the option adjusted spread (OAS). Although this dissertation does not address OAS, this review covers a few studies that employ this new methodology as an alternative to the type of analysis performed in this dissertation. In a chronology of techniques used to analyze mortgage markets, Hu (1990) stated that understanding mortgage products leads to more investment and tighter yield spreads between mortgages and Treasuries.

Hayre (1990) presented a general overview of OAS. He observed that in the analysis of MBS, financial firms widely adopted the method of OAS. For securities with cash flows that were interest-rate dependent, Hayre described a security's OAS as the additional return over the on-the-run Treasury rate that compensated for the embedded options of the risky security. Because they recognized that interest rates were stochastic, OAS methods provided a universally applicable valuation measure for security comparisons.

Differences between OAS estimates among Wall Street were due to prepayment assumptions and adjustments made to the distribution of interest-rate paths. If interest rate changes were assumed to have a bell-shaped probability curve, resulting rates may be unreasonable. So, mean reversion adjustments were assumed by the analysts. Predictably, the adjustments varied to generate distinct OAS values. The prepayment model dictates the level and frequency of cash flows. Hayre recognized that prepayment models generated different cash flow projections and therefore OAS estimates were dissimilar. More detailed analysis of the OAS method was presented by Smith (1991) and Hutchinson and Zenios (1991).

Smith (1991) explained the OAS approach to valuing MBS. Because static yields assumed timely payments and reinvestment at the contract rate, the return from MBS was overstated. The OAS approach was developed by financial firms to reflect rational prepayment of a mortgage when the prevailing mortgage rate fell below the contract rate.

The OAS approach made prepayment a function of interest rates. Using either simulations or the lattice approach, the analyst projected future cash flows and interest rates by assigning probabilities to future rate changes.[74] Then, the cash flows were discounted by the option adjusted yield to the current price. The OAS was the option adjusted yield less a comparable duration Treasury rate.

---

[74] A volatility estimate limited the movement of rates and the timing and level of payments. Although Smith acknowledged that age and location of the mortgage affected prepayment, these factors were not captured in the simple model. He also assumed no default, no maturity premium, a flat yield curve, and 3% refinancing costs.

Smith (1991) suggested that the OAS approach provided investors with a risk neutral approach for comparing the interest-rate risk as well as the cash flow and yield measures for MBSs with alternative investments. When rates fell below the contract rate, static yield analysis suggested a price increase. Because the subsequent cash flows became zero upon prepayment, the present value of the security decreased. Smith (1991) warned that the OAS approach was not appropriate for identifying abnormal returns and was very sensitive to the assumptions and the discounting method.[75]

Hu (1990) recounted assumptions needed for sophisticated measures of total returns for mortgage securities: (1) the slope and the level of the Treasury yield curve, (2) the expected prepayment rate, (3) the yield spread of the mortgage over the comparable Treasury, and (4) the reinvestment rate. With many variables, constraints, and periods, the OAS method can be a computational challenge.

Hutchinson and Zenios (1991) were primarily concerned with efficiency of computer applications. They described the process of programming the calculations required for option adjusted analysis of MBS. The phases of valuing interest-rate-contingent cash flows were:

1.) Generation of arbitrage-free interest rate scenarios that were consistent with the prevailing term structure of interest rates.

---

[75] Some researchers preferred to discount at realized interest rates rather than the current rate.

2.) Generation of cash flows along each interest rate scenario.

3.) Using the interest rates from phase 1 and the cash flows from phase 2 to compute either the expected net present value or an option adjusted spread over the Treasury yield curve.

They employed an interactive system for sensitivity analysis using parallel computing techniques on supercomputers.

Because the valuation of complex securities required simulations of cash flows in a volatile interest rate environment, the procedures were computationally intensive. The complexity stemmed from factors outside the characteristics of the pool that may affect the option's value--the level, structure, and history of interest rates, the market perception of future interest rates, as well as total and disposable consumer income. The enormous number of calculations involved monthly intervals for a 30-year mortgage. If interest rates were modeled on a binomial lattice (where each node could lead to either an up or down movement), the number of interest rate scenarios that could lead to the 360 possible states at the end of the period was 2^{360}. For each scenario, up to 1,000 paths were needed to get acceptable prices.

The interest rate scenarios could be modeled by either Monte Carlo simulation of a diffusion process, or on the sampling of binomial lattices. In a simulation of a diffusion process, Hutchinson and Zenios assumed that interest rates followed a lognormal distribution with mean reversion that forced the simulated rates within historical limits. These drift factors were estimated by requiring that the present value of the on-the-run Treasuries equaled current market prices. Alternatively, interest rates could be estimated by a discrete binomial process.

The cash flow estimates had three components. the interest portion of the monthly payment, the principal portion of the monthly payment, and the projected principal prepayment. Among the approaches to estimate the projected monthly prepayment were

1.) The PSA model expected prepayment rates to increase linearly for the first 30 months of the mortgage until they reached a rate of 6%. The prepayment remained constant thereafter. This model assumed that the level of prepayment was independent of the prevailing interest rates.[76]

2.) The Bear-Stearns model projected prepayment rates as monthly survivorship factors in tabular form. Each table had dimensions of the age of the mortgage and the range of possible interest rates. A 10% range of interest rates was divided into 1,000 - 0.01 basis point increments. This required 360,000 entries for a 30 year mortgage.

Hutchinson and Zenios assumed deterministic prepayment rates that increased at 50% of the benchmark PSA model for the first 30 months and at 3% thereafter. For each iteration, survivorship factors from the prepayment table were used to compute the monthly cash flow.

Each iteration generated a series of short-term forward rates, cash flows at every period, and the market price. The most cumbersome part of the calculations involved the mortgage balance that was recursively dependent on the principal portion of scheduled and unscheduled payments. The OAS over the short-term rates equated the expected present value of the MBS cash flows under all scenarios to the market price. The application used by Hutchinson and Zenios parallelized the simulation procedure to generate multiple paths simultaneously.

---

[76] For a model relating prepayments to prevailing interest rates, see Schwartz and Torous (1989)

This review does not discuss the Hutchinson and Zenios detailed comparison of computer and real times for the option adjusted analysis when performed on different computers. Interestingly, they mentioned that solution time did not decrease linearly with more computing capacity (more parallel calculations) because as more units were employed, there was an increase in the communication needs across the network. Although the discussion focused on estimating OAS for a single security, the authors noted that in a portfolio analysis that the interest rate scenarios would be generated only once.

Summary of Yield Spread Studies

The studies in this section indicated that the mortgage yield spread was affected by property and borrower characteristics as well as traditional measures of default, prepayment, and marketability. Some spreads were found to be sensitive to termination assumptions, compounding errors, insurance provisions, rules regarding due on sale clauses, and the general level of interest rates.

This dissertation extends Ryding's (1990) analysis of the absolute mortgage yield spread by applying a relative spread approach as in KNG (1989), BGS (1981), and Lamy and Thompson (1988). Additional contributions are made by: (1) examining interactive effects as in Lamy and Thompson (1988), and (2) introducing unique agency market share measures, which partition the liquidity measure used by Ryding (1990). Details of the methodology used in this dissertation are presented in Chapter 3.

CHAPTER 3
ANALYSIS OF THE CONVENTIONAL MORTGAGE YIELD SPREAD[1]

This chapter discusses the contributions of this dissertation, tests the dependent variable, compares explanatory measures used in the current model with prior studies, replicates a prior study, and states the model tested herein. Additionally, this chapter presents the implied assumptions, the hypotheses, and a description of the data used. The chapter ends with an examination of the results and their implications.

Contribution of Current Study

This section describes the unique features of this dissertation. The current analysis of the impact of mortgage securitization on the yield spread between the conventional mortgage rate and the 10-year U.S. Treasury rate (CONV-TREAS) examines the dependent variable of the absolute mortgage yield spread and later the relative spread using both linear and interactive models. Effects of default risk, prepayment risk, liquidity risk, as well as the removal of usury ceilings are captured. The relative spread considers the economic incentive

---

[1] See Table 3-1 for Summary of Variables Used in Chapter 3.

Table 3-1

Summary of Variables Used in Chapter 3

AAA = Moody's Corporate Bond Survey Aaa bond rate

AAA-TREAS = Spread between the AAA corporate bonds rate and the ten year Treasury note rate

ABSCHG = The absolute (positive) value of the prior month's Treasury rate minus the current month's Treasury rate

CONV = Effective rate on loans closed for fixed-rate 1- to 4-family conventional mortgages

CONV-TREAS = Spread between conventional mortgage rate and ten-year U.S. Treasury note rate

ONREG = TREAS before usury ceiling removal and zero thereafter; Proxies for the operation of usury ceilings before 1983

%FHLMC = ratio of the FHLMC mortgage pool to the total mortgages pooled

%FMHA = ratio of the FMHA mortgage pool to the total mortgages pooled

%FNMA = ratio of the FNMA mortgage pool to the total mortgages pooled

%GNMA = ratio of the GNMA mortgage pool to the total mortgages pooled

%POOL = ratio of total mortgages pooled to total mortgages outstanding

%PRIV = ratio of the Private mortgage pool to the total mortgages pooled

TREAS = Ten-year U.S. Government Treasury note rate

Note: When these variables are preceded by "R", they are calculated as indicated above and divided by the Treasury rate to create a relative variable.

to prepay based on interest rate levels. This dissertation offers an additional contribution by extending the model to include interactive terms between the default and liquidity variables, as well as between the prepayment and liquidity variables. The interactive analysis separates effects that are confounded in the linear models. Lastly, this dissertation isolates the basis point effects of liquidity measures on CONV-TREAS. Before developing the model for this dissertation, alternative methodologies are reviewed.

Alternative Methodologies

The approach used in this dissertation can be appreciated when the limitations of alternative methodologies are considered. Many mortgage studies are conducted using option pricing models (OPMs) and option adjusted spread (OAS) analysis.[2] The nonapplicability of OPMs for mortgage market analysis lie in the required assumptions. OPMs assume continuous trading, perfect markets, a consul rate and an instantaneous rate. Since mortgage markets tend to violate these assumptions, OPM studies requiring these conditions for the pricing of mortgage related securities could render biased results due to the potentially inappropriate assumptions.[3]

Because mortgage securities trade in markets that suspend operations, the continuous trading assumption is violated. The consul and instantaneous rates do not exist and are usually approximated by a long-term rate (10 to 30 years) and a short-term rate (90-days to 1-year), respectively. In perfect markets, there are no taxes, no transactions costs and perfect divisibility of securities. If these assumptions held, there would be no motivation to create mortgage-backed securities (MBSs). Since this dissertation tests the impact of securitization, assumptions that eliminate the impetus for MBSs are relaxed.

---

[2] For a discussion of OPM and OAS studies, see Chapter 2.

[3] Cunningham and Hendershott (1984) and Buser and Hendershott (1984) provide evidence that options on residential mortgage contracts were not appropriately priced by OPMs.

The other methodology commonly used by financial firms is the OAS. The biggest deterrent for employing OAS is its computational intensity. The OAS analysis is normally conducted on supercomputers that model interest rate behavior, project mortgage cash flows, and calculate present values. Hutchinson and Zenios (1991) note that interest rates can be estimated using either Monte Carlo simulation or binomial lattices. Both these methods require the monthly estimate of interest rates. Additionally, the cash flows have multiple components and depend on the prepayment assumptions.[4] To obtain reasonable prices, the computer program requires a mean-reversion adjustment. These calculations are not necessary in the model used in this dissertation.

This dissertation recognizes the conclusions of OPM studies like Kau, Keenan, Muller, and Epperson (1987, 1992) and Hendershott and Van Order (1987). They agree that substitution effects occur between the mortgagor's options to prepay or default. In this dissertation, supporting evidence of these substitution effects suggests that CONV-TREAS is better specified when controlling for prepayment incentives, default risk, and liquidity risk.

---

[4] Brennan and Schwartz (1985) find that mortgage value varies with prepayment assumptions. Hendershott, Shilling, and Villani (1983) report large compound errors when prices are based on rates computed with faulty prepayment assumptions.

The next section highlights other studies that employed linear models to examine security yield spreads.

Studies Using Linear Regression

The yield differentials between securities have also been modeled using linear estimates. Bond spreads are modeled using linear regression by Fair and Malkiel (1971), Ferri (1978), Fisher (1959), and Lamy and Thompson (1988). Fair and Malkiel focus on the supply differential as a measure of the liquidity premium embedded in two bond yield spreads. Ferri looks at not only liquidity, but also examines the effects of default and prepayment risk. Fisher ignores prepayment risk and explains the bond yield premium in terms of default and marketability. Lamy and Thompson ignore liquidity, but introduce relative yield spreads, which they explain with prepayment and default variables. This dissertation directly measures the default, liquidity, and prepayment effects.

Other mortgage yield spread studies employing linear methodologies include: Sandor and Sosain (1975), Haney (1978), Black, Garbade, and Silber--BGS (1981), Milonas (1987), Rothberg, Nothaft, and Gabriel--RNG (1989) and Ryding

(1990).[5] Sandor and Sosin concentrate on the default premium only. The remaining mortgage spread studies consider premia for the complex set of options in mortgages. For example, Hendershott and Van Order (1989) integrate the OPM and linear approaches by estimating prices with OPMs and inferring a perfect market rate. They test the relationship between mortgage rates and the perfect market rate. Otherwise, the linear models do not employ option pricing techniques.

In the next section, the current model is developed and the measures used in this dissertation are contrasted with the explanatory variables from earlier models of yield spreads.

The Development of the Model

This section tests the dependent variable, discusses alternatives for independent variables, and presents a statement of the current model. Additionally, this section specifies the assumptions and the hypotheses of this dissertation

Dependent Variable

This chapter studies the CONV-TREAS spread during periods of structural change in the mortgage market. Table 3-3 gives

---

[5] Milonas (1987) and RNG (1989) used an ordinary least squares model adjusted by a Cochrane-Orcutt correction for multicollinearity. For a comparison of details regarding previous yield spread studies, see Table 3-2, Panels A and B.

Table 3-2 Panel A
Summary of Previous Mortgage Yield Spread Studies

MORTGAGE ARTICLE	METHOD EMPLOYED	OBSERVATION PERIOD	ABSOLUTE/ RELATIVE	DEPENDENT VARIABLE	PREPAYMENT MEASURE	DEFAULT MEASURE	LIQUIDITY MEASURE	OTHER INC VARIABLES
Black Garbade and Silber (1981)	Regression and LogLikeliGNMA	71 78	Relative	FHA TREAS FHA GNMA GNMA TREAS	GNMA None	+BAA AAA GNMA	#5 GNMA Volume GNMA Volume	+Svc Costs +FHA Ceiling
Edmister and Merriken (1989)	Nonlinear	81 82	Absolute	CONV TREAS FHA TREAS VA-TREAS ARM TREAS	+HighRateAdj's	+LTVR Insurance	None	+Depository Institution
Kenny (1978)	Linear Regression	71-76	Absolute	AAA GNMA	+PrompPar +FHLB Advance	+Borrower's Conf Index	+Bid-Ask	+Duration $Taxation
Hendershott and Shilling (1989)	OLS	78 and 86	Absolute	CONV	None	+LTVR	Loan Size +ConformLimit Sig in '86	GNMA
Hendershott, Shilling and Villani (1983)	Capped Quoted to Actual	74 82	Absolute	CONV TREAS GNMA TREAS FHLMC TREAS	+Rule of Thumb	None	None	+Compounding Error
Hendershott and Van Order (1989)	Linear Regression	81 88	Absolute	CONV	None	None	None	+Perfect Market Rate (For all risks)
Milonas (1987)	Cochrane Orcutt Regression OLS adj	71 85	Absolute	GNMA TREAS	+TREAS3mo Treas10yr 3mo +FHA ?Volatility	None	+GNMA apps GNMAs Issued	+Housing Starts ?HB Change +?ht stddev
Rothberg Nothaft and Gabriel (1989)	Cochrane-Orcutt OLS adj	71 87	Relative	GNMA TREAS FHLMC TREAS	+Volatility +YC Slope	None +A AAA	Relative New MBS Supply TOT other	None
Ryding (1990)	Linear	65 88	Absolute	CONV TREAS	+AAA-TREAS	+AAA TREAS	?POOL	-DEREG +ARMOrigen
Sandor and Sosin (1975)	OLS	67 71	Absolute	MtgE Prime	GNMA	+LTVR +Second Mtg Loan Term	None	Others Nonsig +FairPropCond GoodPropCond

Note: See Legend at Panel E

Table 3-2 Panel B
Summary of Previous Bond Yield Spread Studies

BOND ARTICLE	METHOD EMPLOYED	OBSERVATION PERIOD	ABSOLUTE/ RELATIVE	DEPENDENT VARIABLE	PREPAYMENT MEASURE	DEFAULT MEASURE	LIQUIDITY MEASURE	OTHER IND VARIABLES
Fair and Malkiel (1971)	Linear Regression	61-69	Absolute	UTIL-TREAS IND-TREAS	None	None	+Supply Differential	None
Ferri (1978)	OLS	37-75 60-75	Absolute	UTIL-TREAS IND-TREAS IND-UTIL	NSYrs of TTM on Callable & CallDefer NS90dayTreas	#ValDurabGp NSLiv Yield #IndexLagInd	+Supply Differential	None
Fisher (1959)	Linear Regression	'27, '32, '37, '49, and '53	Absolute	IND-TREAS	None	+Earnings Var -Solvency Per Equity/Debt	MktValBonds	None
Lamy and Thompson (1988)	Linear Regression	73-83	Absolute & Relative Relative more stable	AAA-TREAS	+Volatility +Callfeature Treas nonsig	+Sinking fund -Size (sig/high ratings) -Rating	None	Quartile (1 and 4; DBS Change (+sig/Relative)

Legend for Table 3-2 Panels A and B.
- + Precedes an independent variable that was found to have a positively significant relationship with the dependent variable(s)
- - Precedes an independent variable that was found to have a negatively significant relationship with the dependent variable(s)
- NS Precedes an independent variable that was found to have a nonsignificant relationship with the dependent variable(s)
- $ Precedes an attribute measured by multiple variables found to have offsetting effects. Therefore the results were nonconclusive
- # Precedes an independent variable where the sign of the parameter differs from one dependent variable to the next. Therefore, the independent variable has an uncertain relationship with the spreads measured

Table 3-3
Simple Statistics

Chapter Variable	N	Mean	Std Dev	Median	Minimum	Maximum
AAA-TREAS	68	0.008574	0.005215	0.007800	-0.000100	0.021100
ABSCHG	68	0.002434	0.002081	0.001850	0	0.009200
CONV-TREAS	68	0.020310	0.005411	0.020150	0.010900	0.033000
DEREG	68	0.049603	0.051125	0.057150	0	0.153200
%FHLMC	68	0.173524	0.092634	0.166692	0.031608	0.325859
%FNMA	68	0.189835	0.146459	0.207673	0.000059785	0.475625
%FHMA	68	0.082211	0.091675	0.032903	0	0.271600
%GNMA	68	0.537748	0.085699	0.544430	0.365608	0.560228
%POOL	68	0.138423	0.079638	0.118783	0.028078	0.264279
%PRIV	68	0.016681	0.031712	0	0	0.081221
RAAA-TREAS	68	0.105224	0.080618	0.061914	-0.000737	0.311209
RABSCHG	68	0.025113	0.021311	0.019403	0	0.118252
RCONV-TREAS	68	0.225870	0.073167	0.218566	0.080383	0.393805
RDEREG	68	0.526412	0.502845	1.000000	0	1.000000
R%FHLMC	68	1.850987	1.241868	1.497975	0.460752	4.549762
R%FNMA	68	2.239111	2.140212	1.692914	0.000740	6.988515
R%FHMA	68	0.421711	1.118063	0.252856	0	3.361168
R%GNMA	68	5.948237	1.450361	5.204621	4.131351	9.606937
R%POOL	68	1.511037	0.967764	0.972957	0.399407	3.543055
R%PRIV	68	0.191271	0.368258	0	0	0.986416

Note: See Table 3-1 for variable definitions.

simple statistics for the variables used in this chapter. Of particular current interest are the statistics for the CONV-TREAS spread. Over the observation period, CONV-TREAS ranged from 1.09% to 3.3% with a median of 2.015% and a mean of 2.03%. The standard deviation was 0.5411%. Although these percentages are small, the economic impact is large. Since mortgages represent the largest source of private debt, a small increase in a relevant interest rate can generate significant interest income for lenders. Additionally, small interest rate decreases can affect mortgagor decisions to borrow or prepay.

Table 3-4 reports t-tests of the hypothesis that the CONV-TREAS spread is significantly different from zero. Regardless of the time segment used, the CONV-TREAS spread is significant. The time segments are divided by dates that coincide with either new regulations or mortgage security innovations. None of the events drives the CONV-TREAS spread to zero.

The conventional mortgage yield spread compensates conventional mortgage holders for risks present in conventional mortgages that are absent in Treasury securities. Mortgage lenders require compensation for the additional default and prepayment risk for residential real estate loans. The CONV-TREAS spread also covers servicing costs and tax differences between the two securities. The large secondary market for Treasury securities provides investors quick liquidation opportunities. Although there is a growing and active secondary mortgage market, it is dwarfed by the trading activity of U.S. Treasury instruments. Therefore, mortgage investors also demand a liquidity premium. This dissertation tests various measures of the liquidity premium while controlling for default and prepayment. The alternative measures of the determinants of the conventional mortgage yield spread are presented below.

Table 3-4
Paired t - Test of the CONV-TREAS Yield Spread

	N	t-value
Panel A		
Full Period (3/74-12/90)	66	30.9511
Panel B		
Test of Securitization		
(3/74-9/81) Other	31	21.9636
(12/81-3/87) FNMA	22	16.0614
(6/87-12/90) Private	15	17.2600
Test of Effect of ARMs		
(3/74-12/80)	26	21.5067
(3/81-12/90)	40	22.4379
Test of Effect of Usury		
(3/74-12/82)	36	22.7743
(3/83-12/90)	32	23.4312
Test of Combined Effects		
(3/74-12/80) Other	28	21.5067
(3/81-9/81) ARMs	3	9.7321
(12/81-12/82) FNMA	5	20.0360
(3/83-3/87) Usury	17	15.9436
(6/87-12/90) Private	15	17.2600

Note: The purpose of this table is to test the hypothesis that the CONV-TREAS spread is significantly different from zero. Time segments reflect the introduction of the indicated structural changes. The size of N reports the number of observations in each time segment. The numbers reported in the table are t-values for the indicated dates. T-values above 2.0 show that the spread is significantly different from zero at the 5% level.

Independent Variables

This section presents explanatory measures used by prior studies that use linear regression to explain yield spreads.

After prior evidence is revealed, the measures used in this dissertation are presented. The determinants of mortgage yield spreads that are discussed include default, the prepayment incentive, and liquidity differences between securities. Last, a category of other measures used to explain yield spreads is presented.

Measures for Default Premium

Possible measures for the default premium are numerous. Analysts of bond yield spreads model default with measures that reflect economic conditions, circumstances of a particular company, or characteristics of a specific security issue. Ferri (1978) proxies default in bond spreads with the market value of new orders for durable goods, the Standard & Poor's 500 Stock Index dividend yield, and the Composite Index of Leading Indicators. Fisher (1959) relies on corporate financial position to estimate default risk. Fisher reports that bond yield spreads have a positive relationship with earnings variability and negative relationships with the equity to debt ratio and the period of solvency. Lamy and Thompson (1988) prefer issue specific features as indicators of default. They note negative reactions of bond yield spreads to issue size and rating. If an issue has a sinking fund, Lamy and Thompson report a higher bond yield spread

In most studies of mortgage yield spreads, the measures of default reflect the economy or the terms of the mortgage contract. Sandor and Sosin (1975) go a step further and include variables to capture the negative effect of property condition on the mortgage yield spread. The mortgage contract measures include the loan term,[6] the loan-to-value ratio (LTVR),[7] and the existence of mortgage insurance.[8] An economic measure of investor perception of default, Barron's Confidence Index has a positive relationship with the AAA-GNMA spread in a study by Haney (1978).

Other studies use yield spreads to capture economic measures of default risk. BGS (1981) tested relative mortgage yield spreads for FHA-TREAS and its components--FHA-GNMA and GNMA-TREAS. BGS (1981) measure the default risk in FHA-GNMA with the spread between bonds rated BAA and AAA and finds an increase in the mortgage yield spreads when the default risk rises. A similar measure of default risk is used by RNG (1989). In tests of the FHLMC-TREAS spread, RNG (1989) use the spread between bonds rated A and AAA as a proxy for default risk and find a positive relationship. This dissertation is most similar to tests in Ryding (1990).

---

[6] Used by Sandor and Sossin (1975), who find that increases in loan term decrease the spread between mortgage contract rates and the prime rate.

[7] Sandor and Sossin (1975), Edmister and Merriken (1988), found a positive relationship between LTVR and the mortgage yield spread. Hendershott and Shilling (1989) report that the conventional mortgage rate increases when LTVR goes up.

[8] Edmister and Merriken (1988) capture this feature in a nonlinear model that shows a reduction in mortgage yield spreads for conventional, FHA, VA, and ARM rates over Treasury rates when contracts are insured.

Ryding uses the AAA-TREAS spread to capture default risk and finds that CONV-TREAS increases as AAA-TREAS increases.

Measures for Prepayment Premium

Prepayment risk is ignored in bond yield spread studies by Fisher (1959) and Fair and Malkiel (1971) and in mortgage yield spread studies by Sandor and Sosin (1975). The studies that adjust for prepayment use a diverse set of proxies to capture the incentives for borrowers to prepay. Among studies that find positive relationships between mortgage yield spreads and proxies for prepayment are Edmister and Merriken (1988), who measure prepayment risk with the speed of mortgage rate adjustment to changes in market conditions. Haney (1978) measures prepayment by the excess price over par for premium securities and by the volume of FHLB Advances.

In Ferri (1978), the net of the yields-to-maturity for a callable bond and a call deferred bond represents the premium that investors demand on a security with a call feature. When that measure is not available, Ferri uses the rate on a Treasury security. A Treasury security rate was also used by Lamy and Thompson (1988) and by Milonas (1987). Although Lamy and Thompson find significant results with the Treasury rates only during periods of high interest rates, they find significantly positive relationships between the bond yield spread and the existence of a call feature or high volatility.

Lamy and Thompson (1988) also indirectly control for prepayment risk in their tests of bond yield spreads relative to a Treasury rate. They find that parameter estimates are more stable when the relative yield spread is used as a dependent variable. RNG (1989) also test relative spreads for mortgages securities and find a positive relationship with the interest rate volatility prepayment proxy and a negative relationship with the slope of the yield curve. This dissertation tests both the absolute and relative mortgage yield spread by directly controlling for prepayment incentives due to both the level of and the change in interest rates.

Measures for Liquidity Premium

BGS (1981) and Milonas (1987) find a significantly negative relationship between the GNMA-TREAS yield spread and GNMA volume as a measure of liquidity. Milonas (1987) reports an increase in the spread as GNMA applications increase. Other studies using volume measures to estimate liquidity include Fisher (1959), Fair and Malkiel (1971), and Ferri (1978). Haney (1978) finds a positive relationship between the AAA-GNMA yield spread and the bid-ask spread for GNMAs. Hendershott and Shilling (1989) find that loans ineligible for securitization have a larger liquidity premium. RNG (1989) find that as MBS supply increases and as CMOs are introduced the mortgage yield spread falls.

This dissertation is most comparable to Ryding (1990) who measured liquidity in CONV-TREAS by the percentage of outstanding mortgages that are securitized (@POOL). Ryding found that as the percentage increased, conventional mortgage holders required a smaller liquidity premium. This dissertation tests not only the impact of %POOL, but also tests the affect of the market share of agencies active in the secondary mortgage market. The test of the liquidity premium is the focus of this dissertation. Therefore, the model controls for default and prepayment to isolate the affect of various measures of liquidity on the mortgage yield spread.

As of December 1990, the percentage of mortgages pooled (%POOL) was 28.63%[9]. In the secondary market, the major players are government and quasi-government agencies. For a more detailed analysis, the independent variable %POOL is partitioned into its components.[10] The private secondary market participants maintain a minor market share. As of December 1990, the private market share of total mortgages securitized was only 7.62%. The agency market shares were much larger. The GNMA dominated with 36.86% followed by the FHLMC with 28.66% and FNMA with 27.16%. The other agency considered is FMHA. Although due to an accounting change in 1986, the FMHA is effectively phased out by the end of the observation period; FMHA was a major player in the secondary mortgage market during the earlier years.

---

[9] This represents $1.1 trillion mortgages pooled out of $3.85 trillion mortgages outstanding.

[10] See Table 3-3 for simple statistics of %POOL, agency, and private market share variables.

In preliminary tests of CONV-TREAS, the traditional volume measures for liquidity were not significantly related to the mortgage yield spread. Market share measures are used because they capture the competitive affect that each agency has on secondary mortgage market activity. A major aim of this study is to discover which market share measure better predicts the liquidity premium embedded in the mortgage yield spread.

This dissertation tests six measures of liquidity to estimate which will better estimate the liquidity premium embedded in the mortgage yield spread. The measures of the liquidity premium reflect the percentage of total mortgages that are securitized (%POOL), the market share held by government agencies in the secondary mortgage market (%GNMA, %FMHA, %FHLMC, and %FNMA), and the private market share (%PRIV).

Before discussing the design for those tests, the next section identifies other determinants of mortgage yield spreads.

Measures for Other Yield Spread Determinants

Other factors that affect mortgage yield spreads include regulatory changes and other mortgage market practices. Haney (1978) finds larger mortgage yield spreads for mortgage instruments with higher duration. Haney also finds significant taxation effects on the mortgage yield spread. BGS (1981) find that increases in servicing costs and in the

FHA ceiling correlate with higher mortgage yield spreads. When housing starts increase, Milonas (1987) finds that the yield spread falls. Milonas also reported a significant increase in the standard deviation of interest rates after the 1979 change in Federal Reserve Bank (FRB) policies.

The FRB change has a positive impact on mortgage yield spreads and a similar impact on bond yield spreads in Lacy and Thompson (1988). Edmister and Merriken (1988) find that depository institutions command a higher mortgage yield spread to compensate for services rendered that are unavailable from other mortgage issuers. Ryding (1990) controls for the removal of usury ceilings on financial institution deposits and the introduction of ARMs. Ryding (1990) finds that CONV-TREAS falls after the usury change and increases after ARMs enter the primary mortgage market. Because of the similarities with the current study, Ryding (1990) is replicated in Appendix A.

Statement of the Model

This study recognizes that the mortgage yield spread depends on three premia--the default risk premium, the prepayment (or call) premium, and the liquidity premium. The general statement of the models tested herein is

(3-1) SPREAD = f (DEFAULT, PREPAYMENT, LIQUIDITY)

The tests in this chapter consider the mortgage yield spread as the dependent variable--CONV-TREAS. The measure of default is the difference between the yield on Moody's high investment grade corporate bonds and the 10-year U.S. Treasury note (AAA-TREAS).[11] Prepayment risk is captured by ABSCHG, the absolute (positive) value of the prior month's Treasury rate minus the current month's Treasury rate. In relative tests, the 10-year U.S. Treasury note yield (TREAS) provides additional control for the incentive to prepay.[12] The focus of this study is to identify an adequate measure of the liquidity premium embedded in the mortgage yield spread.

In Table 3-5, the pairwise correlations between market share measures are significant, so it would be redundant to include more than one market share in the same model. Therefore, they are tested separately. The other concern revealed in the correlation matrix of absolute variables (Table 3-5, Panel A) is the significant correlation between the default risk variable with %GNMA and DEREG. The correlation matrix of relative variables (Table 3-5, Panel B)

---

[11] This measure is borrowed from the analysis by Ryding (1990), who suggests that the AAA-TREAS spread would capture not only default risk, but also some of the premium for prepayment risk.

[12] Ferri (1978) and Milonas (1987) used Treasury interest rates as a forecast of future Treasury rates. This proxy for prepayment suggests that a borrower has incentives to prepay if the market rate of interest is below the contract rate of interest. We noted the pairwise correlation of the historical default premium (AAA-TREAS) with the level of Treasury interest rates was -72.5%. With such a high degree of negative correlation, we concluded that the AAA-TREAS variable and TREAS should not appear in the same model because it would produce unreliable parameter estimates. In the relative tests, TREAS is used in the reciprocal form as an interaction with each absolute independent variable

Table 3-5 Panel A
Correlation Matrix of Chapter 3 Absolute Variables

	CONV-TREAS	AAA-TREAS	ABSCHG	%POOL	%GNMA	%FMHA	%FHLMC	%FNMA	%PRIV	DERREG
CONV-TREAS	1.0000 (0.000)	0.3531 (0.003)	0.2963 (0.014)	-0.1376 (0.263)	0.1528 (0.214)	0.1468 (0.232)	-0.2047 (0.094)	-0.1617 (0.188)	-0.1974 (0.107)	0.3416 (0.004)
AAA-TREAS		1.0000 (0.000)	0.2052 (0.093)	-0.1452 (0.237)	-0.4524 (0.000)	0.1443 (0.240)	-0.0965 (0.434)	0.0800 (0.814)	0.0406 (0.742)	-0.3187 (0.008)
ABSCHG			1.0000 (0.000)	0.2052 (0.093)	0.0776 (0.530)	-0.1915 (0.119)	0.1506 (0.220)	0.1251 (0.309)	0.0179 (0.885)	0.0324 (0.793)
%POOL				1.0000 (0.000)	-0.6014 (0.000)	-0.9974 (0.000)	0.9541 (0.000)	0.9511 (0.000)	0.7175 (0.000)	-0.5480 (0.000)
%GNMA					1.0000 (0.000)	0.5998 (0.000)	-0.6026 (0.000)	-0.7893 (0.000)	-0.7179 (0.000)	0.7951 (0.000)
%FMHA						1.0000 (0.000)	-0.9550 (0.000)	-0.9488 (0.000)	-0.7179 (0.000)	0.5490 (0.000)
%FHLMC							1.0000 (0.000)	0.9170 (0.000)	0.5493 (0.000)	-0.6717 (0.000)
%FNMA								1.0000 (0.000)	0.7530 (0.000)	-0.7825 (0.000)
%PRIV									1.0000 (0.000)	-0.5102 (0.000)
DERREG										1.0000 (0.000)

Note: This table lists the pairwise correlations between measures investigated in this chapter. Significant correlations have Pr values (in parenthesis) less than 0.05

Table 3-5 Panel B
Correlation Matrix of Chapter 3 Relative Variables

	BCONV-TREAS	RAAA-TREAS	RABSCHG	RSPOOL	RSGNMA	RSFMMA	RSFHLMC	RSFNMA	RSPRIV	RDERED
BCONV TREAS	1.0000 (0.0001)	0.7688 (0.0001)	0.2913 (0.4293)	-0.1956 (0.1103)	0.5263 (0.000)	0.3717 (0.1583)	-0.2008 (0.1011)	0.1308 (0.2881)	0.0659 (0.5931)	0.2567 (0.0351)
RAAA TREAS		1.0000 (0.0001)	0.0650 (0.593)	-0.0112 (0.928)	0.5142 (0.000)	0.2406 (0.0481)	-0.0340 (0.7781)	0.0870 (0.4811)	0.0973 (0.4301)	-0.0435 (0.7251)
RABSCHG			1.0000 (0.000)	0.0839 (0.497)	0.2284 (0.061)	-0.1240 (0.3141)	0.0551 (0.6561)	0.1191 (0.3711)	0.0502 (0.6841)	-0.0946 (0.4431)
RSPOOL				1.0000 (0.000)	-0.6000 (0.0001)	-0.6913 (0.0001)	0.9702 (0.0001)	0.9176 (0.000)	0.6073 (0.0001)	-0.8631 (0.0001)
RSGNMA					1.0000 (0.0001)	0.7844 (0.0001)	0.4473 (0.0001)	0.6248 (0.0001)	0.4404 (0.0001)	0.5734 (0.0001)
RSFMMA						1.0000 (0.0001)	-0.8657 (0.0001)	0.9262 (0.000)	-0.7219 (0.0001)	0.8556 (0.000)
RSFHLMC							1.0000 (0.000)	0.8963 (0.000)	0.8138 (0.0001)	-0.8481 (0.0001)
RSFNMA								1.0000 (0.000)	0.7284 (0.0001)	0.9057 (0.000)
RSPRIV									1.0000 (0.0001)	-0.5585 (0.000)
RDERED										1.0000 (0.000)

Note: This table lists the pairwise correlations between measures investigated in this chapter. Significant correlations have Pr values (in parenthesis) less than 0.05.

reveals a significant correlation between the relative default risk variable and the relative market share measures for GNMA and FMHA. If the multicollinearity is severe, parameter estimates from models with AAA-TREAS and %GNMA or AAA-TREAS and DEREG could be unreliable. Therefore, this dissertation estimates condition indices for each version of the model to determine the degree of multicollinearity.

With the conventional mortgage yield spread over the 10-year Treasury note rate as the spread and the percentage of mortgages pooled as the liquidity measure, a more specific statement of one model tested herein is

(3-2) CONV-TREAS = f (AAA-TREAS, ABSCHG, %POOL)

After this absolute spread analysis is considered with each liquidity measure (%POOL, %GNMA, %FMHA, %FHLMC, %FNMA, and %PRIV), a relative spread methodology is applied. Using a methodology presented in Black, Garbade, and Silber (1981) in the relative models, TREAS serves as an additional measure of prepayment incentives. By dividing both sides of equation 3-2 by the Treasury interest rate, the following model results:

(3-3) (CONV-TREAS)/TREAS =
f((AAA-TREAS)/TREAS, ABSCHG/TREAS, %POOL/TREAS)

For ease of notation, this model can be restated as:

(3-4) RCONV-TREAS = f(RAAA-TREAS, RABSCHG, R%POOL)

By dividing by the Treasury rate, the dependent variable becomes the conventional mortgage yield minus the Treasury interest rate relative to the Treasury rate. This measure is also known as the relative yield spread.[13] The relative yield spread allows us to measure how the mortgage yield spread changes, controlling for fluctuations in the general level of interest rates. Similarly, the default and liquidity measures are relative to changes in interest rates. The relative liquidity measures are denoted R%POOL, R%GNMA, R%FMHA, R%FHLMC, R%FNMA, and R%PRIV.

Using the relative measures of the mortgage yield spread allows each independent variable to interact with the inverse of the Treasury rate, and provides additional control for prepayment risk. Another advantage of deflating both sides of equation 3-2 by the yield on the 10-year Treasury note is the reduction in heteroscedasticity of the residuals generated by the regression models.[14] However, in the analysis and interpretation of parameter values from equation 3-4, the relative measures require an adjustment that will be discussed later in this chapter.

The design of the model tested in this dissertation implies certain assumptions about the operation of mortgage markets. These assumptions are discussed in the next section.

---

[13] Lacy and Thompson (1988) analyze bond contracts using relative yield spreads. Rothberg, Nothaft and Gabriel (1989) use relative spread analysis to compare GNMA and FHLMC rates to Treasury rates.

[14] See Black, Garbade, and Silber (1981).

Implied Assumptions of this Dissertation

Because service fees have not been controlled for, they are implicitly assumed to have either a zero or a constant value. However, transactions costs have not been completely ignored. Some transactions costs and market imperfections must exist to justify the creation of MBSs. Although the absolute models ignore taxes, taxes are considered in the relative spread. Rothberg, Nothaft, and Gabriel (1989) suggest that the use of relative measures adjust for differences in taxation.

Additional relaxation of the perfect market assumption relates to the divisibility of mortgage contracts. Because the MBS issuers have a comparative advantage at pooling and distributing MBS cash flows, imperfect divisibility is also implied. Since differences in the mortgage and Treasury rates are expected, the assumption that the two securities are not perfect substitutes is also required.

With the above assumptions for the previously described model, the hypotheses for the tests relate to the anticipated reaction of the conventional yield spread to its determinants. Specific Hypotheses of this dissertation are stated below

Specific Hypotheses

The hypotheses for the effects of the independent variables on the CONV-TREAS mortgage yield spread are

Table 3-6
Hypotheses for the CONV-TREAS Yield Spread Equation

Independent Variables	Hypothesized Sign and Significance
AAA-TREAS	+/sig
ABSCHG	+/sig
%POOL	-/sig
%GNMA	nonsig
%FMHA	nonsig
%FHLMC	-/sig
%FNMA	-/sig
%PRIV	nonsig
DEREG	?/?

Note: This table summarizes the hypotheses for the parameters in the regression estimates for the CONV-TREAS yield spread. The + or - signs project the direction of the relationship. The relationships that are expected to be significant are labeled "sig". The relationships that are expected to be nonsignificant are labeled "nonsig". Uncertain relationships are labeled "?".

presented in Table 3-6. An hypothesis of this dissertation is that there will be a significantly negative relationship between the spread and the default premium--AAA-TREAS. This dissertation projects a significantly negative relationship between the spread and %POOL, %FHLMC, and %FNMA. The anticipated reduction in the spread due to bigger %POOL, %FHLMC, and %FNMA reflects the increased liquidity that in turn causes a decrease in the liquidity premium for the conventional mortgage rate.

Nonsignificant relationships between the CONV-TREAS spread and the GNMA and FMHA market share variables are expected because conventional mortgages are privately insured and GNMA and FMHA repackage government insured mortgages. A nonsignificant relationship with %PRIV is expected because the private market share is so small compared to the entire market of securitized mortgages that an impact on the CONV-TREAS spread is not expected. Lastly, the DEREG variable relationship with the spread is uncertain. The impact of this measure of usury abolition could effect the cost of lending and the competition among lenders. If the higher cost of lending effect dominates, then the CONV-TREAS spread should increase. If the competitive effect dominates, it is possible that the conventional rate will fall and the CONV-TREAS spread will be smaller.

These hypotheses are tested after the data are described in the following section.

Data

The observation period of this dissertation is from March 1974 to December 1990. The quarterly data come from the Federal Reserve Bulletin, The Mortgage Bankers Association Magazine, and the Moody's Bond survey.[15] Although the GNMA agency pass-through security was first issued in 1970, the consistent reporting of the volume of issues did not begin until 1974. Therefore, the observation period began four years after the initial issuance of GNMA agency pass-through securities. An objective of this dissertation is to capture the effect of structural changes in the market. Since volume and market share changes are not observed during the introduction, it is possible that the tests in this study will not capture the full impact of introducing GNMA securities.

---

[15] See the "Key for Symbols or Abbreviations" for variable descriptions. For data sources, refer to Appendix B For time series graphs of selected data, see Figures 1-1 through 1-4.

The only other data problem noted was with the GNMA interest rate. The Mortgage Bankers Association rates were used because they reported effective rather than contract rates. However, from March 1974 to June 1977, only the GNMA bid yields were available. To test the reasonableness of the series of bid yields as a substitution for effective rates, a correlation analysis of the series against a series of contract rates reported in the Federal Reserve Bulletin was performed. A third series of rates used the Federal Reserve Bulletin contract rates to fill the gap in the effective rates. The pairwise correlations between the three series ranged from 99.3% to 99.7%. Therefore, it appears that the three series of GNMA rates were practically identical.

Tests of the CONV-TREAS Absolute Mortgage Yield Spread

The parameters for the linear models were estimated using the Ordinary Least Squares (OLS) method of regression analysis. OLS was chosen because of its ability to generate condition indices in the statistical program employed. The condition indices measure multicollinearity, which the correlation matrices (at Table 3-5, Panels A and B) indicated could be a concern for a few of the models tested herein. The parameters for the interactive models were estimated using Generalized Least Squares (GLS) estimates because of the ability of GLS to accommodate interactive variables in the statistical program employed. Due to the reduction in heteroscedasticity, GLS provides more reliable parameter estimates than OLS. The interactive variables are used to evaluate the effect of structural changes in the mortgage yield spread. Unfortunately, the condition index could not be estimated for the interactive models.

The linear equations for the CONV-TREAS absolute mortgage yield spread regressions are presented in Table 3-7. Regardless of the structural change variable used, the default risk and prepayment risk measures are always significantly positive. This supports the hypotheses that investors will require a premium to compensate for exposure to default and prepayment risk. Among the liquidity and structural change variables, %GNMA, %FNMA and the DEREG variables have significant parameter estimates. Contrary to expectations, the increase in the market share of mortgages pooled by GNMA causes an increase in the CONV-TREAS spread. It appears that the competition of additional GNMA mortgage securities increase the liquidity premium in the conventional mortgage rate. The negative sign of the %FNMA parameter is appropriate

Table 3-7
Linear Equations for the CONV-TREAS Absolute Yield Spread

Intercept	0.0166	0.0025	0.0141	0.0168	0.0158	0.0154	0.0121
	(9.166)	(0.582)	(9.332)	(9.931)	(10.782)	(10.680)	(5.607)
AAA-TREAS	0.3364	0.4881	0.3131	0.3266	0.3642	0.3557	0.4478
	(2.616)	(4.228)	(2.664)	(2.821)	(3.263)	(3.139)	(4.320)
ABSCHG	1.0417	0.9874	1.0293	1.0476	1.0197	0.9749	0.8993
	(3.642)	(3.643)	(3.673)	(3.666)	(3.642)	(3.433)	(3.509)
%POOL	-0.0118						
	(-1.676)						
%GNMA		0.0209					
		(3.044)					
%FMHA			0.0063				
			(1.213)				
%FHLMC				-0.0106			
				(-1.640)			
%FNMA					-0.0134		
					(-2.184)		
%PRIV						-0.0311	
						(-1.890)	
DEREG							0.8464
							(4.309)
R^2	0.2548	0.3238	0.2433	0.2571	0.2795	0.2590	0.4000
Adjusted R^2	0.2199	0.2921	0.2078	0.2223	0.2458	0.2242	0.3719
F-Value	7.294	10.217	6.860	7.384	8.297	7.466	14.221
Condition index	6.713	18.728	6.632	7.061	6.447	5.189	6.727

Note: T-values are reported in parenthesis

since FNMA securitizes conventional mortgages. Therefore as the %FNMA increases, investors will demand a lower liquidity premium for CONV-TREAS. The DEREG variable shows that when usury ceilings were removed, the spread increased by 4.54%. This implies that the cost of funds rose as depositors could demand competitive interest rates from financial institutions and that this effect dominated the potential rise in competition that could have led to lower rates.

In Table 3-8, Panels A and B report the regression results for the absolute spread considering the interaction of the default and prepayment risk variables with the liquidity and the structural change variable. The interaction parameters detect the direction of a shift (if any) in the relationship between the mortgage yield spread and the default premium (and the prepayment premium) due to changes in the market share measures of liquidity or the structural change measured in the interactive variable DEREG. The interaction results are more revealing than the linear models.

When interaction is considered, explanatory power of each model increases (except the model using %PRIV as a liquidity measure). In Panel B of Table 3-8, the private market share measure continues to have no influence on the spread. The DEREG model gains the most from considering the interaction term. Only the prepayment variable is nonsignificant and the explanatory power increases from 37.19% in the linear model to 57.62% in the interactive model. The interpretation of the interaction term requires differential calculus, which will be discussed in the summary of this chapter when the basis point effects of the interaction equations are presented.

Next, the convention mortgage yield spread is tested using a relative yield spread

Table 3-8
Interactive Equations for Absolute CONV-TREAS Yield Spread

Panel A The Impact of Government Agency Market Share					
Intercept	0.0166 (5.56)	0.0024 (0.24)	0.0098 (3.31)	0.0193 (6.26)	0.0147 (4.29)
AAA-TREAS	0.0282 (0.14)	2.4073 (2.26)	0.9658 (3.14)	0.1645 (0.83)	0.2910 (2.68)
ABSCHG	2.8977 (4.26)	-5.0983 (-2.75)	1.1343 (2.28)	3.2250 (4.72)	3.0970 (5.03)
%POOL	0.0275 (1.27)				
AAA-TREAS*%POOL	6.1747 (2.18)				
ABSCHG*%POOL	-12.3636 (-2.93)				
%GNMA		0.0193 (1.09)			
AAA TREAS*%GNMA		3.4781 (1.84)			
ABSCHG*%GNMA		11.0659 (3.32)			
%FNMA			0.0199 (1.51)		
AAA TREAS*%FNMA			2.2137 (2.17)		
ABSCHG*%FNMA			5.5192 (2.24)		
%FHLMC				0.0412 (2.22)	
AAA-TREAS*%FHLMC				4.6181 (3.23)	
ABSCHG*%FHLMC				11.1880 (3.39)	
%FHMA					0.0311 (1.71)
AAA TREAS*%FHMA					4.5026 (2.64)
ABSCHG*%FHMA					-10.2878 (-3.20)
R^2	0.3805	0.4573	0.3485	0.4612	0.4449
Adjusted R^2	0.3403	0.4135	0.2960	0.4177	0.4001
F Value	7.91	10.45	6.63	10.62	9.94

Note: t values are reported in parenthesis

Table 3-6--Continued

Panel B The Impact of Other Structural Changes

Intercept	0.0153	0.0063
	(10.04)	(4.76)
AAA-TREAS	0.3502	1.1662
	(3.01)	(6.67)
ABSCHG	1.0479	0.2222
	(3.37)	(0.79)
%PRIV	-0.0510	
	(-0.64)	
AAA-TREAS*%PRIV	4.3276	
	(0.49)	
ABSCHG*%PRIV	-6.6341	
	(-0.61)	
OEREG		0.0822
		(3.60)
AAA-TREAS*DEREG		-11.1496
		(-4.55)
ABSCHG*OEREG		11.6269
		(3.09)
R^2	0.2666	0.6078
Adjusted R^2	0.2075	0.5762
F-Value	4.51	19.22

Note: T-values are reported in parenthesis.

Tests of the CONV-TREAS Relative Mortgage Yield Spread

The results of the linear tests of the CONV-TREAS relative yield spread are presented in Table 3-8. The relative default risk measure consistently has a positive significant

Table 3-9
Linear Equations for the Relative CONV-TREAS Yield Spread

Intercept	0.1369 (10.544)	0.1011 (4.136)	0.1352 (12.600)	0.1368 (10.382)	0.1372 (12.429)	0.1366 (12.650)	0.1245 (11.107)
0864 TREAS	0.7398 (11.090)	0.6728 (8.808)	0.7387 (9.078)	0.7395 (11.570)	0.7401 (11.641)	0.7387 (11.594)	0.7239 (11.689)
RANGCVG	0.5056 (2.085)	0.5729 (2.374)	0.5012 (2.055)	0.5046 (2.081)	0.5127 (2.121)	0.5025 (2.088)	0.5531 (2.366)
REPOOL	0.0011 (0.232)						
RSIGMA		0.0064 (1.542)					
RRFMMA			0.0001 (0.034)				
RX/RLMC				0.6069 (-0.172)			
RSFNMA					0.0026 (-0.514)		
RAPRIV						0.0064 (0.457)	
RDEREG							0.2018 (2.183)
R^2	0.6868	0.6981	0.6848	0.6868	0.6881	0.6859	0.7167
Adjusted R^2	0.6733	0.6877	0.6701	0.6782	0.6714	0.6711	0.6929
F-Value	46.431	48.873	48.359	46.389	46.637	46.579	51.430
Condition Index	5.808	15.029	4.575	5.625	4.464	4.370	4.898

Note: All variables are standardized by the Treasury Rate. T-values are reported in parenthesis.

relationship with the relative yield spread. RCONV-TREAS is significantly positively related to RDEREG. However, RCONV-TREAS lacks significant relationships in the linear models with the liquidity variables when they are divided by the Treasury rate. As with the absolute spread analysis, the relative analysis is more meaningful when interaction terms are included in the model.[16] A key contribution of this dissertation is evidence in the opposing signs of the liquidity measures and the interaction terms, which suggest that the effects are confounded in the linear models.

Though the GNMA and FMHA market share measures in Table 3-10, Panel A do not significantly influence the relative CONV-TREAS spread. When %GNMA interacts with RABSCHG, the relationship with CONV-TREAS is significantly positive This suggests that as prepayment risk increases, the relationship between CONV-TREAS and %GNMA is direct. The interaction of %FMHA with RAAA-TREAS shows a significantly negative effect on CONV-TREAS This indicates that when default risk increases, the relationship between the spread and the market share for FMHA is indirect. It appears that the competitive effects of securitization of nonconventional mortgages were confounded in the linear analysis When %FNMA and %FHLMC interacts with RAAA-TREAS, there is a significantly negative relationship. The interaction of %FNMA and %FHLMC with RABSCHG is nonsignificant.

Whereas the absolute models explained up to 57.62%, the relative models each explain more than 66% of the variation in both the linear and interactive models of the mortgage yield spread. Although the interaction term does not improve the explanatory power of the model when R%PRIV is used as a

---

[16] See Table 3-10.

Table 3-10
Interactive Equations for Relative CONV-TREAS Yield Spread

Panel A The Impact of Government Agency Market Share					
Intercept	0.1253 (7.78)	0.0666 (2.22)	0.1156 (5.74)	0.1816 (7.55)	0.1379 (10.96)
RAAA TREAS	0.2024 (4.79)	1.5924 (2.80)	1.1161 (7.20)	0.6687 (6.67)	0.6678 (10.63)
RABSCHG	1.2468 (2.12)	0.8846 (-1.62)	0.1769 (0.49)	1.5375 (2.56)	0.8107 (2.39)
R%POOL	0.0295 (-1.75)				
RAAA TREAS*%POOL	3.7809 (2.54)				
RABSCHG*%POOL	4.8716 (-1.46)				
R%GNMA		0.0091 (1.35)			
RAAA TREAS*%GNMA		1.7198 (-1.37)			
RABSCHG*%GNMA		6.3415 (2.24)			
R%FNMA			0.0142 (1.92)		
RAAA TREAS*%FNMA			1.6027 (-2.72)		
RABSCHG*%FNMA			2.4176 (1.44)		
R%FHLMC				-0.0270 (-1.94)	
RAAA TREAS*%FHLMC				3.2813 (2.82)	
RABSCHG*%FHLMC				-5.129 (-1.92)	
R%FMMA					0.0307 (-2.97)
RAAA TREAS*%FMMA					2.9740 (2.87)
RABSCHG*%FMMA					4.0537 (-1.42)
R^2 Adjusted R^2 F Value	0.7247 0.7025 32.64	0.7190 0.6963 31.73	0.7218 0.6995 32.10	0.7357 0.7144 34.51	0.7343 0.7129 34.27

Note: All variables are standardized by the Treasury Rate. T values are reported in parenthesis

Table 3-10--Continued

Panel B The Impact of Other Structural Changes

Intercept	0.1376 (12.13)	0.0785 (5.52)
RAAA-TREAS	0.7353 (11.26)	1.3085 (10.27)
RABSCHG	0.4831 (1.79)	0.2036 (0.86)
R%PRIV	-0.0326 (-0.51)	
RAAA-TREAS*%PRIV	2.7237 (0.39)	
RABSCHG*%PRIV	1.6059 (0.19)	
RDEREG		0.0765 (3.78)
RAAA-TREAS*DEREG		-10.1549 (-4.74)
RABSCHG*DEREG		8.9971 (2.44)
R^2	0.6868	0.7957
Adjusted R^2	0.6615	0.7792
F-Value	27.19	48.29
Condition Index	N/A	N/A

Note: T-values are reported in parenthesis.

liquidity measure, the interactive model for RDEREG reigns as a superior model with significant variables and a 77.92% adjusted R-squared value

Summary and Discussion of Basis Point Effects

In the preceding tests of the determinants of the CONV-TREAS mortgage yield spread, the interaction models were powerful and more revealing than the linear models. The interactive models in this study are used to capture the shifts in the relationship between: (1) the CONV-TREAS yield spread and the default premium as the liquidity measure changes, and (2) the CONV-TREAS yield spread and the prepayment premium as the liquidity measure changes. By measuring the effects of the liquidity measure and the interaction of the liquidity measure with the default and prepayment premia, individual and interaction effects can be isolated.

To interpret the interaction models, it is necessary to quantify how much the yield spread changes with a change in liquidity by considering the parameter estimate (β) for the liquidity variable, the parameter estimate for the interaction terms, and the values of the default and prepayment premia. For example, using the absolute CONV-TREAS spread, the %POOL liquidity measure, and the average values of the default and prepayment premia, the computation of the basis point change in the conventional mortgage yield spread due to a 1% increase in the %POOL follows[17]:

---

[17] Refer to Pindyck and Rubinfeld (1981) for econometric analysis of interaction terms.

(3-5) Change

$$= \beta_{\%POOL} + \beta_{(AAA-TREAS)*\%POOL} * (AAA-TREAS) + \beta_{ABSCHG*\%POOL} * (ABSCHG)$$
$$= -0.0275 + (4.1747 * 0.0086) - (12.3838 * 0.0024)$$
$$= -0.0213 \text{ or } -213 \text{ basis points}$$

This formula comes from the differentiation of the entire model in column one of Table 3-8, Panel A, with respect to %POOL.

The relative spread analysis has an additional step. Since each term in the model was divided by the Treasury rate, the results must be multiplied by the Treasury rate to convert back to basis points. Using the relative CONV-TREAS spread, the %POOL liquidity measure, the average value of the default and prepayment premia, and the average value of the Treasury rate, the computation of the basis point change in the mortgage yield spread due to a 1% increase in the %POOL follows:

(3-6) Change =

$$= (\beta_{R\%POOL} + (\beta_{(RAAA-TREAS)*R\%POOL} * RAAA-TREAS)) * TREAS$$
$$= (-0.0295 + (3.703 * 0.0086) - (4.8719 * 0.0024)) * 0.0943$$
$$= -0.0008 \text{ or } -8 \text{ basis points}$$

This formula results from the differentiation of the model described in column one of Table 3-10 Panel A with respect to %POOL.

Since these basis point calculations depend on parameter values, it is important that the parameter estimates be reliable. Because the correlation matrices in Table 3-5 indicated significant correlations between certain independent variables[18], condition indices for the models are reported in Tables 3-7 and 3-9. Gujarati (1988) reports that some authors believe the condition index is the best available multicollinearity diagnostic. Condition indices between 10 and 30 indicate moderate to strong multicollinearity and over 30 suggests severe multicollinearity. None of the condition indices for the models reported in Tables 3-7 and 3-9 reveal severe multicollinearity. The models of %GNMA and R%GNMA have moderate to strong multicollinearity as reflected in condition indices of 18.728 and 13.029, respectively.

The procedure in equations 3-5 and 3-6 are followed for the absolute and relative models, respectively. The basis point reactions of the yield spread in the interactive models are presented in Table 3-11. The table compares the basis point effects in the absolute models to the relative models. It is obvious at first glance that the absolute yield spread models report a larger basis point reaction than the relative yield spread models. It appears that the excess of the absolute model basis points over the relative yield spread basis points represent changes in the spread due to changes in interest rates that are not isolated in the absolute model.

When interest rate movement is accounted for, the basis point effect from the relative models presents a less noisy (more pure) measure of the changes in the liquidity premium

---

[18] Specifically, significant correlations were noted between AAA-TREAS and %GNMA, AAA-TREAS and DEREG, RAAA-TREAS and R%GNMA, as well as RAAA-TREAS and R%FNMA.

Table 3-11
Basis Point Effects of Liquidity Measures on the CONV-TREAS Yield Spread

Panel A
Assumes *Average* Values for Default Risk and Treasury Rate

Liquidity Measure	Absolute Yield Spread Model	Relative Yield Spread Model
%POOL	-213^{4}	-8^{5}
%GNMA	$+159^{7}$	$+9^{7}$
%FMHA	$+142^{4}$	$+6^{6}$
%FHLMC	-264^{1}	-11^{6}
%FNMA	-161^{4}	-6^{2}
%PRIV	-297^{8}	-5^{8}

Panel B
Assumes *December 1990* Values for Default Risk and Treasury Rate

Liquidity Measure	Absolute Yield Spread Model	Relative Yield Spread Model
%POOL	-253^{4}	-6^{5}
%GNMA	$+199^{7}$	$+10^{7}$
%FMHA	$+156^{4}$	$+5^{6}$
%FHLMC	-289^{1}	-10^{6}
%FNMA	-183^{4}	-4^{2}
%PRIV	-296^{8}	-1^{8}

Note: Values in the table are the basis point change in the CONV-TREAS yield spread for a one percentage change in the indicated liquidity measure. Basis points were calculated according to equation (3-5) for absolute models and equation (3-6) for relative models.

[1] Liquidity, default interaction and prepayment interaction parameters are significant at the 5% level.

[2] Liquidity and default interaction parameters are significant at the 5% level

[3] Liquidity and prepayment interaction parameters are significant at the 5% level

[4] Default interaction and prepayment interaction parameters are significant at the 5% level

[5] Only the liquidity parameter is significant at the 5% level.

[6] Only the default interaction parameter is significant at the 5% level

[7] Only the prepayment interaction parameter is significant at the 5% level

[8] Liquidity, default interaction and prepayment interaction parameters are non significant at the 5% level

due to the various liquidity measures. When interactive terms are used, there is an isolation of an "own-liquidity" effect. The liquidity measure with the largest influence on the CONV-TREAS spread is %FHLMC. This result is reasonable since FHLMC issues mortgage securities involving conventional mortgage contracts. Assuming the average values for default risk and the Treasury rate in Table 3-11, Panel A, %FHLMC causes a reduction in the spread of 11 basis points. Table 3-11 Panel B uses the default premium and Treasury rate for the end of the observation period and shows a slightly smaller reduction in the spread of 10 basis points due to changes in %FHLMC.

The importance of these results can me observed by considering the economic impact of the basis points reported in Table 3-11. The effects of the liquidity measures on the CONV-TREAS yield spread range in absolute magnitude from 1 basis point to 297 basis points (or .01% to 2.97%). This portion of the yield spread represents compensation to the conventional mortgage investors for their exposure to liquidity risk.

An estimate of the monetary impact of a liquidity premium can be estimated by multiplying the percentage times the dollar amount of conventional mortgages in the secondary market. A range of estimates of the economic impact is reported in Table 3-12. Using the minimum, average, and maximum values for the basis point effects and the total conventional mortgages in the secondary market, a minimum,

Table 3-12
Calculation of Dollar Amount for Basis Point Effects

	Minimum	Average	Maximum
FHLMC Issues	738,000,000	83,326,691,000	318,359,000,000
FNMA Issues	0	56,030,691,000	299,833,000,000
Conventionals in Secondary Market	$738,000,000	$139,357,382,000	$616,192,000,000
Minimum Basis Point Effect	0.0001	0.0001	0.0001
Minimum Dollar Amount Effect	$73,800	$13,935,738	$61,619,200
Average Basis Point Effect	0.0112	0.0112	0.0112
Average Dollar Amount Effect	$8,280,975	$1,563,706,967	$6,914,187,733
Maximum Basis Point Effect	0.0297	0.0297	0.0297
Maximum Dollar Amount Effect	$21,918,600	$4,138,914,246	$18,300,902,400

Note: The purpose of this table is to provide estimates of the economic impact of the liquidity premium in the CONV-TREAS spread. The dollar amount effects reported in this table were calculated by multiplying the related basis point effect by the total conventional mortgages in the secondary market. Maximum values correspond to the end of the observation period (December 1990).

average, and maximum value of the dollar amount effect of the liquidity premium of $73,800, $1,563,705,957, and $18,300,902,400, respectively. The maximum value of the dollar amount effect of the liquidity premium corresponds to the end of the observation period (December 1990).

Conclusion

This chapter identifies a linear model that explains the CONV-TREAS mortgage yield spread in terms of default, prepayment, and liquidity risks as well as a structural change due to the removal of usury ceilings. The results show that the model is better specified when the spread is stated relative to the level of interest rates. The relative yield spread model provides additional control for the economic incentive to prepay when interest rates fall below the mortgage contract rate. This result is consistent with the findings of Black, Garbade and Silber (1981) and Rothberg, Nothaft, and Gabriel (1989), who specify mortgage yield spreads in relative terms. Also, the results concur with Lamy and Thompson (1988), who find relative bond yield spreads to have more stable parameter estimates.

An additional contribution of this dissertation is that interactive models partition liquidity effects due to changes in securitization and to changes in the relationship of CONV-TREAS with default and prepayment risk as the composition of the secondary mortgage market changes. Over the observation period, $14,300,902,400 is calculated as the maximum estimate of the economic impact of the liquidity premium.

Unique to this dissertation is the isolation of an "own liquidity" effect. When agency market shares are used to capture liquidity in interactive models of the relative yield spread, the market share of an agency that issues conventional mortgages (FHLMC or FNMA) significantly affects CONV-TREAS.

CHAPTER 4
CONCLUSIONS AND EXTENSIONS

The purpose of this chapter is to synthesize the analyses done in the prior chapter and to identify additional opportunities for related research. After a brief description of the tests that were performed to study the mortgage yield spread, the equations with the highest explanatory power for each approach are presented and interpreted. The chapter concludes with recommendations for extensions in related areas.

Description of Tests

This dissertation tests the CONV-TREAS mortgage yield spread as an absolute spread and as a relative spread. Our examination also considers the linear and interactive expressions of equations for both the absolute and relative spreads. These analytical approaches are described below.

Statement of the Absolute Equations

Though many regression equations were estimated , the expression of the basic model as stated in equation (3-1) is:

(5-1) ABSOLUTE SPREAD = f(DEFAULT, PREPAYMENT, LIQUIDITY)

Controlling for default (AAA-TREAS) and prepayment (ABSCHG), this study focuses on the identification of which of the six measures of liquidity (%POOL, %GNMA, %FMHA, %FNMA, %FHLMC, and %PRIV) best captures the liquidity premium imbedded in the conventional mortgage yield spread. Because of the high collinearity among the liquidity and usury deregulation variables, the effects of agency market share and the structural change that removed usury ceilings from Savings and Loan deposits were separately considered. With the separation came the opportunity to compare the effects of the liquidity measures to the results of the structural change variable to determine which effect dominated as a determinant of the mortgage yield spread. The structural change tests took the following form:

(5-3) ABSOLUTE SPREAD = f (DEFAULT, PREPAYMENT, DEREG)

The absolute spread results are compared to the relative spread tests that are described in the next section.

Statement of the Relative Equations

The relative equations consider additional control for prepayment incentives by dividing both sides of each absolute equation by the Treasury rate. This adjustment controls for the changes in the incentive to prepay with changes in the general level of interest rates. The relative spread measure also controls for differences in taxation, servicing, and other uncontrolled differences between conventional mortgages and 10-year U.S. Treasury securities. The relative equations take the following form:

(5-4) RELATIVE SPREAD =

f (DEFAULT/TREAS, PREPAYMENT/TREAS, LIQUIDITY/TREAS)

Both the absolute and relative spreads are subjected to an interactive analysis that is described below.

Statement of the Interactive Equations

The interactive equations added variables that considered how the effect of the default premium and the prepayment premium on mortgage yield spreads changed with changes in the liquidity or structural change variables. The equations were numerous and therefore are not repeated here.[1]

The next section identifies the preferred version of the model for each approach.

Discussion of Preferred Equations

This section identifies and interprets the equation with the greatest explanatory power for each approach used in Chapter 3 to analyze the mortgage yield spread. In each case, the details of the superior model are presented--including parameters, t-values, F-values, adjusted R-squared values, and the basis point effects isolated by the equation presented. Since each equation had significant F-values (reflecting the robustness of the model), the preferred equations were distinguished by the presence of a significant liquidity parameter and high explanatory power.

---

[1] For a review of the interactive model statements, see Tables 3-8 and 3-10.

Preferred Linear Equation for the Absolute Spread

The most effective equation tested that explains the absolute conventional mortgage yield spread is the model that uses the GNMA market share variable to measure liquidity. The regression generated the equation in the figure

CONV-TREAS =	
Intercept	0.0025 (0.592)
AAA-TREAS	0.4881 (4.228)
ABSCHG	0.9874 (3.643)
%GNMA	0.0209 (3.044)
Adjusted R-Squared	0.2921
F-Value	10.217

Note: T-values are reported in parenthesis.

Figure 4-1 The Preferred Linear Equation for the Absolute CONV-TREAS Yield Spread.

The equation in Figure 4-1 shows a significantly positive relationship between the absolute mortgage yield spread and default, prepayment and liquidity. These relationships show that as the risks to mortgage investors increase, they require premia in the yield spread to compensate for additional risk exposure. The F-value suggests that the equation is robust in its ability to explain the dependent variable. The adjusted R-squared of 29.21% exceeds the explanatory power offered by other equations stated using the absolute approach to analyzing liquidity in the conventional mortgage yield spread.

The parameter value for %GNMA indicates that for every 1% increase in the market share of GNMA, the conventional mortgage yield spread increases by 209 basis points. It appears that as the secondary market for FHA and VA mortgages grows through GNMA issuances, the reduction in comparable liquidity of conventional mortgages is perceived as additional risk for issuers of conventionals. The additional 2.09% return compensates investors for the additional liquidity risk in conventional mortgages versus 10-year Treasury notes.

Preferred Interactive Equation for the Absolute Spread

The preferred model for the absolute conventional mortgage spread when the interactive method is used is featured in Figure 5-2. Although it appears that default no longer has a significant relationship with CONV-TREAS, the default interaction with the liquidity measure is significant. This suggests that as liquidity (measured by %FHLMC) increases, the

CONV-TREAS =	
Intercept	0.0193 (6.26)
AAA-TREAS	-0.1645 (-0.83)
ABSCHG	3.2250 (4.72)
%FHLMC	-0.0012 (-2.22)
AAA-TREAS*%FHLMC	4.8181 (3.23)
ABSCHG*%FHLMC	-11.1080 (-3.39)
Adjusted R-squared	0.4177
F-Value	10.62

Note: T-values are reported in parenthesis

Figure 4-2 Preferred Interaction Equation for Absolute CONV-TREAS Yield Spread

parameter that measures how CONV-TREAS relates to AAA-TREAS will increase.

With the significantly negative parameter estimate for %FHLMC, this dissertation isolates an "own-liquidity effect". It appears that as the market share of an agency that securitizes conventional mortgages increases, the additional liquidity in the secondary market reduces the liquidity premium required by conventional mortgage lenders.

Evidenced by the significantly positive parameter for ABSCHG, prepayment risk also affects the CONV-TREAS spread. However, the significantly negative parameter for the interaction term (ABSCHG*%FHLMC) suggests that as liquidity increases, the impact of prepayment risk on the absolute mortgage yield spread decreases.

To compile the effects of %FHLMC and its interactive effects on CONV-TREAS, the analysis at equation 3-5 as presented in Table 3-11 identifies an average drop of 264 basis points in the spread for a 1% increase in the market share of FHLMC. Using the interactive method, more movements in the absolute spread to the liquidity premium were can attribute than when using the linear method

Preferred Linear Equation for the Relative Spread

The third method used to evaluate the liquidity affects in the conventional mortgage yield spread uses relative equations. The preferred linear equation for the relative spread confirms the significantly positive relationship between the conventional spread and measures of default, prepayment, and liquidity that was observed in the absolute analysis. The results of this regression are presented in Figure 4-3.

The F-Value indicates the significance and robustness of the equation specified in the figure. The adjusted R-squared shows that 68.19% of the volatility in CONV-TREAS is explained. The relative GNMA market share isolates 66 basis points of the relative spread. Comparing the liquidity premium of 209 basis points in the absolute analysis to the relative equation that controls for the general level of interest rates (as well as other differences between the conventional and the 10-year Treasury security), the liquidity premium is substantially reduced.

(CONV-TREAS)/TREAS =	
Intercept	0.1611 (4.138)
RAAA-TREAS	0.6728 (8.806)
RABSCHG	0.5729 (2.374)
RSIGMA	0.0066 (1.542)
Adjusted R-squared	0.6819
F-Value	48.873

Note: T-values are reported inparenthesis.

Figure 4-3 Preferred Linear Equations for Relative CONV-TREAS Yield Spread.

Preferred Interactive Equation for the Relative Spread

The equation exhibiting the greatest explanatory power is revealed in the interactive analysis of the relative conventional mortgage yield spread. With an F-Value of 34.51, the equation in Figure 5-4 explains 71.44% of the volatility in the CONV-TREAS spread. The equation with the "own-liquidity effect" in the significantly negative R%FHLMC reigns explanatory power among the estimated equations for the relative conventional mortgage yield spread.

(CONV-TREAS)/TREAS =	
Intercept	0.1616 (7.55)
RAAA-TREAS	0.4687 (4.47)
RABSCHG	1.5375 (2.56)
R%FHLMC	-0.0278 (-1.54)
RAAA-TREAS*%FHLMC	3.2813 (2.82)
RABSCHG*%FHLMC	-5.129 (-1.82)
Adjusted R-squared F-Value	0.7144 34.51

Note: T-values are reported in parenthesis

Figure 4-4 Preferred Interaction Equation for Relative CONV-TREAS Yield Spread

As with the absolute interactive equation in Figure 4-2, the measurement of the interactive effects between the FHLMC liquidity measure with AAA-TREAS and ABSCHG unveils offsetting effects that are confounded in the linear models. Specifically, the negative parameter for %FHLMC (in Figure 4-2) and R%FHLMC (in Figure 4-4) is offset by the significantly positive parameters for the interactive effects with the default term. These relationships suggest that as liquidity increases, the relationship between CONV-TREAS and default also increases. The negative sign of the interaction of the relative FHLMC liquidity measure with the RABSCHG prepayment measure suggests a decrease in the relationship between RCONV-TREAS and RABSCHG as R%FHLMC increases.

The analysis at equation 3-6 generates the basis point effects of the liquidity and interaction terms in the relative models. Table 3-11 reports that the relative yield spread decreases by 11 basis points for a 1% increase in R%FHLMC.

In the next section, the extensions and related research opportunities are discussed.

Extensions

The natural extension of the mortgage yield spread analysis performed in this study would be to apply the tests to other interest rates. This dissertation focused on the conventional mortgage yield spread involving the primary mortgage market rates for conventional mortgages and the U.S. Treasury rate for 10-year securities. As an extension, similar tests could be done using mortgage yield spreads that involve the primary market rates for FHA and VA lending, or the secondary market rates for GNMA, FHLMC and FNMA.

Specifically, an extension of this dissertation could test for the effects of the government subsidy embedded in the CONV-FHA spread. Other extensions could query how to measure the effects of government subsidies in the following spreads: CONV-VA, FHA-VA, FNMA-GNMA, FHLMC-GNMA, and FHLMC-FNMA.

Additionally, the differences between government mortgage-backed rates and Treasury security rates in the GNMA-

TREAS spread could be analyzed. The analysis of the corresponding FNMA-TREAS and FHLMC-TREAS mortgage yield spreads would reveal if the features for an issuer of FHA-, and VA-backed GNMA securities are appropriate for the issuers of conventional-backed FNMA and FHLMC securities.

In tests of the FHA-GNMA spread, the primary market rate for FHA could be compared with the associated secondary market rate for GNMA. An analogous study of the following spreads could test the liquidity premia in: CONV-FHLMC, CONV-FNMA, and VA-GNMA. Outside the mortgage market, there are many bond market rates that could be subject to parallel testing procedures using comparative analysis of absolute, relative, linear and interactive measures to identify important determinants of yield spreads.

The methods used in this dissertation provide vehicles to evaluate and compare the affects of liquidity, default, and prepayment on the spreads between interest rates. This provides a valuable tool for explaining the different premia required by investors in alternative security markets.

APPENDIX A
THE REPLICATION OF RYDING (1990)

The study whose purpose most closely resembles this dissertation is Ryding (1990). Ryding evaluates the determinants of the conventional mortgage rate. Rather than study the mortgage yield spread, he uses the effective mortgage rates on all conventional home loans closed (fixed and adjustable) as the dependent variable and the weighted average interest rate on Treasury securities (WTREAS) as an independent variable. The calculation of the weighted Treasury rates is an undisclosed weighted average of the ten-year constant maturity Treasury rate and the three-month Treasury bill rate.[2]

The other determinants of Ryding's mortgage interest rate are a default measure, a liquidity measure, and variables to capture the effects of changes in usury laws and the introduction of ARMs. The default risk measure is the yield spread on AAA corporate bonds to ten year Treasury notes (AAA-TREAS). The liquidity measure is approximated by the ratio of pooled mortgages divided by total mortgages on one- to four-family homes (%POOL). To capture the effect of the removal of usury ceilings on deposits in lending institutions, Ryding (1990) uses the rate of Treasury notes before the 1983 abolition of usury ceilings and zero thereafter (USURY). To control for the introduction of ARMs, a dummy variable has a value of zero before 1981 and a value of one thereafter (ARMS). The Ryding model is stated as follows.

---

[2] The Ryding (1990) results address the spread if the weighted treasury rate was subtracted from both sides of the equation.

CONV = f (WTREAS, AAA-TREAS, %POOL, ARMS, USURY)

Table A-1 repeats the equation for the conventional rate that was reported in the Ryding study with an adjusted R-squared of 96.5%. An approximate replication explaining 97.9% of the variability in the conventional mortgage rate is also presented in Table A-1. The Treasury rate and default risk parameter estimates and significance levels are similar for Ryding and the approximate replication. This similarity shows that little is lost when the 10-year Treasury rate is used in the approximate replication in place of the weighted Treasury rates employed in the Ryding study. Sadly, the securitization parameters are dissimilar. Ryding finds the hypothesized significantly negative relationship between the conventional mortgage rate and %POOL, but the approximate replication reveals a nonsignificant relationship. Other major differences in the results occur for the USURY and ARMS parameter.

Some divergence may be due to the inability to replicate the study perfectly. Ryding did not specify the exact weighting factor for the Treasury variable. Though this does

Table A-1
Comparison of Ryding Equation to Approximate Replication

Independent Variables	Ryding Parameters	Approximate Replication Parameters[1]
Intercept	1.2840 (4.50)	-0.0043 (-0.80)
Weighted Average Interest Rate on 10-year Treasury notes[2]	0.9931 (40.77)	1.0901 (23.62)
Yield Spread on AAA Corporate bonds to ten-year notes (AAA-TREAS)	0.6260 (5.71)	0.6436 (5.66)
Share of mortgage stock securitized (%POOL)	-3.492 (-3.31)	0.0243 (1.69)
Rate on Treasury notes before abolition of usury ceilings (USURY)	-0.0441 (-1.96)	0.0859 (5.19)
Dummy variable to control for introduction of adjustable-rate mortgages (ARMS)	1.351 (5.10)	0.0023 (0.86)
R^2	Not Reported	0.9792
ADJUSTED R^2	0.965	0.9779
F-Value	Not Reported	582.45

Note: Dependent variable is average effective rate on all conventional home mortgages closed. T-values are reported in parenthesis.

[1] Because of differences in data access, the approximate replication covers 1974 through 1990. The observation period of the Ryding study was 1965 through 1988

[2] The weighted average interest rate on Treasury securities combined the three-month Treasury bill rate with the ten-year Treasury note rate where the bill rate was somehow weighted by ARMs in new mortgages closed (zero before 1982). The approximate replication simply used the ten-year Treasury rate for this variable

not seem to affect the Treasury parameter, the impact on other parameters is unknown. Because of differences in data access, Ryding studied 1965-1988 and the approximate replication begins in 1974 and ends in 1990. Perhaps the effects of %POOL, USURY, and ARMS changed in the later period.

In Table 3-4, this dissertation reports paired t-tests of the mortgage yield spread that found the spread to be significantly different from zero in each time segment around the structural changes in the mortgage market. In the examination in this chapter, a methodology that partitions the liquidity measure is adopted to isolate the source of the liquidity effect. Further, this dissertation avoids a weakness of the Ryding model that is discussed and quantified below

A major deficiency in Ryding's 1990 analysis is the high levels of multicollinearity in the independent variables.[3] In Table 3-5, a correlation matrix for various structural change variables shows the lack of independence between the Ryding explanatory variables that are labeled %POOL, ARMS, and USURY. The pairwise correlations between these three variables range from 74% to 85%. By including these three variables in his model, Ryding (1990) presents redundant explanatory variables that yield unreliable parameter estimates. This dissertation adopts a methodology that avoids the multicollinearity problem. To avoid repeating Ryding's error of combining highly collinear independent variables, the effects %POOL and USURY are analyzed separately.

---

[3] The presence of highly collinear independent variables violates an assumption of the classical linear regression model. As the collinearity of two independent variables approaches unity, their standard errors approach infinity and the parameter values are rendered meaningless.

Additionally, Ryding (1990) does not consider ARMs during 1978-1981. Federally chartered S&Ls were authorized to issue ARMs in 1979 and National Banks were authorized to offer ARMs in 1981.[4] Since the adoption of ARMs was sluggish at inception, the 1981 assumption is probably reasonable. Another weakness of the ARMS dummy variable is that it is confounded with the inception of S&L participation in the secondary mortgage market. This dissertation adds a measure of prepayment risk and omits the ARMs variable because it is significantly collinear with all the prepayment measures considered. The ARM variable appeared most expendable because the introduction of adjustable-rate mortgages corresponded to periods of high interest rates, which are controlled for with the prepayment measure.

---

[4] Source: Congressional Budget Office Study, The Housing Finance System and Federal Policy: Recent Changes and Options for the Future. Congress of the United States, October 1983.

APPENDIX B
DATA SOURCES

The first four data points were obtained from various issues of *Mortgage Banking* (formerly *Mortgage Banker*).

CONV	Effective rate on loans closed for fixed-rate conventional mortgages on 1- to 4-family mortgages
FHA	Secondary market gross yields for new homes financed by FHA mortgages from the FHA Opinion Survey
GNMA	Current secondary market yields for pools of mortgages guaranteed by GNMA
TREAS	Ten-year U.S. Government Treasury note rate
AAA	Aaa bond rate was obtained from various issues of the *Moody's Corporate Bond Survey*.
DEREG	TREAS before abolition of usury ceilings and zero thereafter proxies for the operation of usury ceilings before 1983.

The next six data points were obtained from various issues of the *Federal Reserve Bulletin*

MTGOS	Total outstanding principal balances of mortgages for all holders and types of property
MTGPOOL	Total outstanding principal balances of mortgage pools backing securities insured or guaranteed by private and federal agencies for residential property
GNMAPOOL	Outstanding principal balances of mortgage pools backing securities insured and guaranteed by the Government National Mortgage Association for residential property
FHLMCPOOL	Outstanding principal balances of mortgage pools backing securities guaranteed by the Federal Home Loan Mortgage Corporation for residential property

FMHAPOOL Outstanding principal balances of mortgage pools backing securities guaranteed by the Farmers Home Administration for residential, commercial and farm property. Due to accounting changes by FMHA, the securities were reallocated from mortgage pools to mortgage holdings in the forth quarter of 1986.

FNMAPOOL Outstanding principal balances of mortgage pools backing securities guaranteed by the Federal National Mortgage Association for residential property

Calculated Values

CONV-TREAS = Spread between conventional mortgage rate and the ten year U.S Treasury note rate

CONV-FHA = Spread between conventional mortgage rate and the FHA insured mortgage rate

FHA-GNMA = Spread between FHA insured mortgage rate and the GNMA guaranteed rate

GNMA-TREAS = Spread between the GNMA guaranteed rate and the 10-year U.S. Treasury note rate

AAA-TREAS = Spread between the AAA corporate bonds rate and the ten year Treasury note rate

Relative spreads adjust for the general level of interest rates as follows:

(CONV-TREAS)/TREAS
(CONV-FHA)/TREAS
(FHA-GNMA)/TREAS
(GNMA-TREAS)/TREAS
(AAA-TREAS)/TREAS

%POOL = MTGPOOL/MTGOS This ratio of total mortgages pooled to total mortgages outstanding approximates the share of mortgages that are securitized.

%GNMA = GNMAPOOL/MTGPOOL This ratio of the GNMA mortgage pool to the total mortgages pooled approximates the market share that the GNMA holds in the secondary mortgage market.

%FHLMC = FHLMCPOOL/MTGPOOL This ratio of the FHLMC mortgage pool to the total mortgages pooled approximates the market share that the FHLMC holds in the secondary mortgage market.

%FMHA = FMHAPOOL/MTGPOOL This ratio of the FMHA mortgage pool to the total mortgages pooled approximates the market share that the FMHA holds in the secondary mortgage market.

%FNMA = FNMAPOOL/MTGPOOL This ratio of the FNMA mortgage pool to the total mortgages pooled approximates the market share that the FNMA holds in the secondary mortgage market.

%PRIV = PRIVPOOL/MTGPOOL This ratio of the Private mortgages pooled to the total mortgages pooled approximates the market share held by private firms in the secondary mortgage market.

BIBLIOGRAPHY

Anderson, Gary, and Raymond Chiang. "Interest Rate Risk Hedging for Due-On-Sale Mortgages with Early Termination." *Journal of Financial Research*, 10:2 (Summer 1987), 133-142.

Black, Deborah G., Kenneth D. Garbade, and William L. Silber "The Impact of the GNMA Pass-Through Program on FHA Mortgage Costs." *Journal of Finance*, 36:2 (May 1981), 457-469.

Black, Fischer, and Myron Scholes, "The Valuation of Option Contracts and a Test of Market Efficiency," *Journal of Finance*, 26 (May 1972), 399-418.

Black, Fischer, and Myron Scholes, "The Pricing of Options and Corporate Liabilities," *Journal of Political Economy*, 81 (May-June 1973), 637-659.

Brennan, M., and E. Schwartz. "Savings Bonds, Retractable Bonds and Callable Bonds." *Journal of Financial Economics* 5 (1977), 67-88.

Brennan, M. J., and E. S. Schwartz "A Continuous Time Approach to Pricing Bonds," *Journal of Banking and Finance*, 3 (1979), 133-155.

Brennan, M., and E. Schwartz "Determinants of GNMA Mortgage Prices." *American Real Estate and Urban Economics Association Journal*, 13:3 (1985), 209-228.

Buser, S. A., and P. H. Hendershott, "Pricing Default-Free Fixed-Rate Mortgages." *Housing Finance Review*, 3 (October 1984), 405-29.

Campbell, Tim, and J. Kimball Dietrich. "The Determinants of Default on Insured Conventional Residential Mortgage Loans." *Journal of Finance*, 38:5 (December 1983), 612-647.

Clauretie, Terrence M. "The Impact of Interstate Foreclosure Cost Differences and the Value of Mortgages on Default Rates. *Journal of the American Real Estate and Urban Economics Association*, 15:3 (Fall 1987), 152-167

Congressional Budget Office. "The Housing Finance System and Federal Policy: Recent Changes and Options for the Future." Congress of the United States, Washington, DC, October 1983.

Cunningham, Donald F. and Patric H. Hendershott. "Pricing FHA Mortgage Default Insurance." *Housing Finance Review*, 3:4 (1984), 373-92.

Curley, Anthony J., and Jack M. Guttentag. "The Yield on Insured Residential Mortgages." *Explorations in Economic Research*. 1:1 (Summer 1974), 114-161.

Curley, Anthony J., and Jack M. Guttentag. "Value and Yield on Insured Residential Mortgages." *Journal of Finance*, 32:2 (May 1977), 403-416.

Downs, Anthony. *The Revolution in Real Estate Finance*, The Brookings Institution, Washington, DC, 1985.

Dunn, Kenneth B., and John J. McConnell. "A Comparison of Alternative Models for Pricing GNMA Mortgage-Backed Securities." *Journal of Finance*, 36:2 (May 1981a), 471-484.

Dunn, Kenneth B., and John J. McConnell. "Valuation of GNMA Mortgage-Backed Securities." *Journal of Finance*, 36:3 (June 1981b), 599-616.

Dunn, Kenneth B., and K. J. Singleton. "An Empirical Analysis of the Pricing of Mortgage-Backed Securities." *Journal of Finance*, 38:2 (May 1983), 613-623.

Edmister, Robert O., and Harry Merriken. "Pricing Efficiency in the Mortgage Market." *American Real Estate and Urban Economics Association Journal*, 16:1 (Spring 1988), 50-62.

Fair R. C., and Malkiel B. G., "The Determinants of Yield Differentials Between Debt Instruments of the Same Maturity." *Journal of Money, Credit and Banking*, 3:4 (November 1971), 733-745.

Ferri, Michael G. "An Empirical Examination of the Determinants of Bond Yield Spreads." *Financial Management*, 7:3 (Autumn 1978), 40-46.

Fisher, Lawrence. "Determinants of Risk Premiums on Corporate Bonds." *Journal of Political Economy*, 67:3 (June 1959), 217-237

Green, Jerry, and John B. Shoven. "The Effects of Interest Rates on Mortgage Prepayments." *Journal of Money, Credit and Banking*, 18:1 (February 1986), 41-59.

Gujarati, Damodar N. *Basic Econometrics*, Second Edition. McGraw-Hill Book Company, New York, 1988.

Hall, Arden R., "Valuing the Mortgage Borrower's Prepayment Option." *American Real Estate and Urban Economics Association Journal*, 13:3 (1985), 229-247.

Haney Jr., Richard L. "An analysis of Yield Spreads Between Ginnie Mae Pass-Throughs and Aaa Corporate Bonds." *Financial Management*, 7:1 (Spring 1978), 17-28.

Hayre, Lakhbir S. "Understanding Option-Adjusted Spreads and Their Use." *Journal of Portfolio Management*, 16:4 (Summer 1990), 68-69.

Hendershott, Patric R., and James Shilling. "The Impact of the Agencies on Conventional Fixed-Rate Mortgage Yields." *Journal of Real Estate Finance and Economics*, 2.2 (June 1989), 101-115.

Hendershott, Patric H., James Shilling, and Kevin Villani. "Measurement of Spreads Between Yields on Various Mortgage Contracts and Treasury Securities." *Journal of the American Real Estate and Urban Economics Association*, 11:4(1983), 478-490.

Hendershott, Patric H., and Robert Van Order. "Integration of Mortgage and Capital Markets and the Accumulation of Residential Capital." *Regional Science and Urban Economics*, 19:2 (May 1989), 189-210.

Hendershott, Patric H., and Robert Van Order. "Pricing Mortgages: An Interpretation of the Models and Results." *Journal of Financial Services Research*, 1:1987, 19-55.

Hu, Joseph. "The Evolution of Mortgage Research." *Mortgage Banking*, 50:4 (January 1990), 35-39.

Hutchinson, James M. and Stravros A. Zenios. "Financial Simulations on a Massively Parallel Connection Machine" *International Journal of Supercomputer Applications*, 5.2 (Summer 1991), 27-45.

Kau, J. B., D. C. Keenan, W. J. Muller III, and J. F. Epperson. "Valuation and Securitization of Commercial and Multifamily Mortgages." *Journal of Banking and Finance*, 11 (1987), 525-546.

Kau, J. B., D. C. Keenan, W. J. Muller III, and J. F. Epperson. "A Generalized Valuation Model for Fixed-Rate Residential Mortgages." Journal of Money, Credit and Banking, 24:3 (August 1992), 279-300.

Kaufman, George C., and George E. Morgan. "Standardizing Yields on Mortgages and Other Securities." American Real Estate and Urban Economics Association Journal, 8:2 (Summer 1980), 163-179.

Lamy, Robert E., and G. Rodney Thompson, "Risk Premia and the Pricing of Primary Issue Bonds." Journal of Banking and Finance, 12:4 (December 1988), 585-601.

Livingston, Miles B. Money and Capital Markets: Financial Instruments and Their Uses. Prentice Hall, Englewood Cliffs, NJ, 1990.

Lloyd-Davies, Peter. "Packaging Leftovers." Secondary Mortgage Markets, 4:3 (Fall 1987), 2-6.

Longbrake, William A. and Manferd O. Peterson. "Regional and Intra Regional Variations in Mortgage Loan Rates." Journal of Economics and Business, 31:2 (Winter 1979), 75-83.

Maisel, Sherman J. Real Estate Finance. Harcourt, Brace, Jovanovich, Inc., Orlando Florida, 1987.

Meador, Mark. "The Effects of Mortgage Laws on Home Mortgage Rates." Journal of Economics and Business, 34:2 (1982), 143-148.

Merton, Robert C. "Theory of Rational Option Pricing," Bell Journal of Economics and Management Science, 4 (Spring 1973), 141-183.

Merton, Robert C. "On the Pricing of Corporate Debt: The Risk Structure of Interest Rates," Journal of Finance, 29 (May 1974), 449-470.

Milonas, Nikolaos T. "The Prepayment Option in the GNMA-Treasury Bond Spread." Housing Finance Review, 6:4 (Winter 1987), 261-278.

Novick, Barbara and Virginia Barrett. Mortgage-Related Securities Guide. The First Boston Corporation, New York, July 1985.

O'Keefe, Michael, and Robert Van Order. "Mortgage Pricing: Some Provisional Empirical Results," American Real Estate and Urban Economics Journal, 18:3 (1990), 313-322.

Pindyck, Robert S., and Daniel L. Rubinfeld. Econometric Models and Economic Forecasts. McGraw-Hill, New York, 1981.

Quigley, John M., and Robert Van Order. "Efficiency in the Mortgage Market: The Borrower's Perspective." American Real Estate and Urban Economics Association Journal, 18:3 (1990), 237-252.

Radcliffe, Robert. Investment. Scott, Foresman and Company, Glenview, IL, 1987.

Rothberg, James P., Frank E. Nothaft, and Stuart A. Gabriel. "On the Determinants of Yield Spreads Between Mortgage Pass-Through and Treasury Securities." Journal of Real Estate Finance and Economics, 2:4 (December 1989), 301-315.

Ryding, John. "Housing Finance and the Transmission Mechanism of Monetary Policy." Quarterly Review (Federal Reserve Bank of New York), 15:2 (Summer 1990), 42-55.

Sandor, Richard L., and Howard B. Sosin, "The Determinants of Mortgage Risk Premiums: A Case Study of the Portfolio of a Savings and Loan Association." Journal of Business, 48 (January 1975), 27-38.

Schwartz, Eduardo S., and Walter N. Torous. "Prepayment and the Valuation of Mortgage-Backed Securities." Journal Finance, 44:2 (June 1989), 375-392.

Shimko, David C. "The Equilibrium Valuation of Risky Discrete Cash Flows in Continuous Time." Journal of Finance, 44:5 (December 1989), 1373-1383.

Smith, Clifford W. Jr., "Pricing Mortgage Originations." American Real Estate and Urban Economics Association Journal, 10:3 (Fall 1982), 313-330.

Smith, Stephen D. "Analyzing Risk and Return for Mortgage-Backed Securities." Economic Review (Federal Reserve Bank of Atlanta), 76:1 (January/February 1991), 2-11.

Swan, Craig. "Pricing Private Mortgage Insurance." American Real Estate and Urban Economics Association Journal, 10:3 (Fall 1982), 276-296.

Titman, Sheridan, and Walter Torous. "Valuing Commercial Mortgages: An Empirical Investigation of the Contingent-Claims Approach to Pricing Risky Debt." Journal of Finance, 44:2 (June 1989), 345-373.

BIOGRAPHICAL SKETCH

Ivy Denise Locke enrolled in the doctoral program at the University of Florida in finance in 1987. Her areas of interest include teaching business finance, investments, and real estate as well as scholarly research regarding mortgage markets and real estate investments.

In 1984, she received a Master of Business Administration degree from Washington University in St. Louis, Missouri, in finance with a minor in marketing. Her undergraduate studies resulted in a Bachelor of Business Administration degree in accounting from Emory University in Atlanta, Georgia, in 1979.

Her professional certifications include the Certificate of Public Accounting (CPA) and a real estate license both in the State of Georgia.

She has worked for The Florida State University; the University of Florida; Spelman College, First National Bank of Atlanta; Washington University; First National Bank of Chicago; North American Van Lines; Deloitte, Haskins, and Sells; Emory University; Lockheed-Georgia Company; McDonald's Corporation; Atlanta Parks and Recreation; Apollo Associates; Inc. and Skipperland Daycare Center.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Miles Livingston

Miles Livingston, Chair
Professor of Finance,
Insurance, and Real Estate

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Halbert C. Smith

Halbert C. Smith
Professor of Finance,
Insurance, and Real Estate

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Wayne R. Archer

Wayne Archer
Assistant Professor of
Finance, Insurance, and Real
Estate

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Jesse V. Boyles

Jesse V. Boyles
Associate Professor of
Accounting

This dissertation was submitted to the Graduate Faculty of the Department of Finance, Insurance, and Real Estate in the College of Business Administration and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August 1993

Dean, Graduate School